

THE NORTHWAY WILD FOOD AND HEALTH PROJECT:  
CONFRONTING THE LEGACY OF TOXIC WASTE ALONG THE ALCAN

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THESIS

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By

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## ABSTRACT

Northway, Alaska is a small, mostly Athabascan community with a large Formerly Used Defense Site located near the Alaska Highway. Despite remediation in the 1990s, residents are concerned about the contamination of wild foods. This Community Based Participatory Research project comprised two studies: the Northway Wild Food Study, to investigate contaminant levels in locally prioritized traditional foods; and the Northway Health Study, to investigate locally suspected links between historic pollution sources and health problems. The project identifies multiple pathways of exposure that were more significant in the past, including a clear water creek, whitefish, a pipeline corridor, and a public water tank. Historic contamination with petroleum, persistent organic pollutants, the ingredients of Agent Orange, and chlorinated byproducts of disinfection, respectively, is neither well documented nor quantifiable. Retrospective cohort comparisons of historic resource users to non-users found complex associations. Reported users showed a higher reported incidence of several health conditions, including cancer, thyroid-, reproductive-, metabolic-, and cardiac problems. This thesis postulates that the situation represents a case study of endocrine disruption via multiple unquantifiable and interactive pathways, including complexity that precludes the establishment of “cause and effect” relationships. However, community based research can improve local and scientific understanding of the repercussions of environmental pollution in rural communities still grappling with the legacy of military waste.

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## LIST OF ACRONYMS

ADEC .....	Alaska Department of Environmental Conservation
ALCAN .....	Alaska Canada Route, the Alaska Highway
ALSIB .....	Alaska-Siberia Route
DDE .....	Dichlorodiphenyldichloroethylene
DDT .....	Dichlorodiphenyltrichloroethane
DM .....	Dames and Moore [remediation contractors]
FAA .....	Federal Aviation Administration
FUDS .....	Formerly Used Defense Site
HFP .....	Haines-Fairbanks Pipeline
OC .....	Organochlorine
PCB .....	Polychlorinated biphenyl
POP .....	Persistent organic pollutant
TCC .....	Tanana Chiefs Conference
TCDD .....	Tetrachlorodibenzodioxin
UAF .....	University of Alaska Fairbanks
US .....	United States
USFWS .....	US Fish and Wildlife Service
USARAL .....	US Army Alaska
USACE-AK .....	US Army Corps of Engineers-Alaska District

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This is a painful story. I am very grateful to Northway residents for sharing it with me and trusting me to write it down. Northway residents played critical roles in the development and implementation of the project, and none of it could have happened without their support. It has been a privilege and, despite the grief, a pleasure to get to know people in the Upper Tanana. There are many people without whom this project would not have happened, from Northway and elsewhere. To begin, I thank Robert Lee Demit for sending me to Northway, Melissa Robinson for taking and introducing me, and Gerald Albert for encouraging me to return.

Guidance for the project was provided by community members and my academic committee. The “Steering Committee” was an informal group of Northway residents and leaders. The members talked about the project among themselves on occasion, but we never met as a group. Rather, I spoke with the members as I moved through the work to seek ideas and opinions on decisions that needed to be made. The individuals to provide such guidance included Gerald Albert, Darlene Northway, Lorraine Titus, Cora Demit, Susie Sam, as well as members of the Health Study Team: Cheri Marunde, Polly Hyslop, Becky Gallen, Jane Fix, and Howard Fix. The study team’s additional volunteer time and energy made the health study possible. Support and relevant insight were also offered by two non-residents who have worked in Northway over decades: Robert Sattler at the Tanana Chiefs Conference (TCC), and Connie Friend at the US Fish and Wildlife Service (retired). They were both very helpful throughout the project, and Bob arranged for funding from TCC to test Moose Creek water.

The findings presented in Chapters 2, 3, and 4 have been submitted to the International Journal of Circumpolar Health as two papers. The first describes the design and findings of the Northway Health Study (Chapter 2) and discusses the results related to Moose Creek and whitefish (Chapter 3), while the second discusses the findings related to the Haines Fairbanks Pipeline (Chapter 4). I am listed as the lead author and the Northway Health Study Team, above, is listed as co-author. No other members of the study team actually wrote those papers or these chapters, but their ideas and efforts greatly contributed to the design, implementation, and reporting of the study. In Chapters 2, 3, and 4, “we” refers to the Health Study Team.

In the summer of 2005 Dena Paul and Eva Thomas, and in 2007 Taniesha Emry, worked as interns for the wild food study, collecting samples and helping me learn about the natural environment and food system around Northway. Time with them was among highlights of the project for me and I wish them all the best.

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I am glad to consider the people I've gotten to know in Northway my friends. Too many individuals to name have made me feel welcome and I am grateful. Ada Gallen provided me a room, good food, and rich stories through much of the fieldwork. From cutting fish to beading, her patient answers to my constant questions taught me much about Northway, and even myself. Malinda Holmes has also been a good friend and advisor, with calm words of wisdom and a rare generosity of spirit. Polly Hyslop has been a critically important colleague, while her outlook and friendship have likewise given me strength and helped me grow. Finally, it would be very difficult to describe what I've learned from Walter Mark. Beyond his skills of reading the landscape, and endless stories about growing up on Charlieskin and Scottie Creeks, Walter is one of the kindest people I have ever known. Paddling with him in the Upper Tanana has been the finest pleasure of all.

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could lead me to reframe my confusion until I understood how to pursue clarification. Elizabeth Guillette's knowledge of the developmental effects of contaminants, and innovative approach to research was both useful and inspiring. I wish we'd had more time together and greatly appreciate her traveling on several occasions to participate in the project. Sven Ebbesson strengthened this work with consistently constructive critique and extensive knowledge of nutrition and metabolism. His clinical epidemiology with Yupik communities in Western Alaska is exemplary research that sought relevance in rural communities long before "Community Based Participatory Research" was coined.

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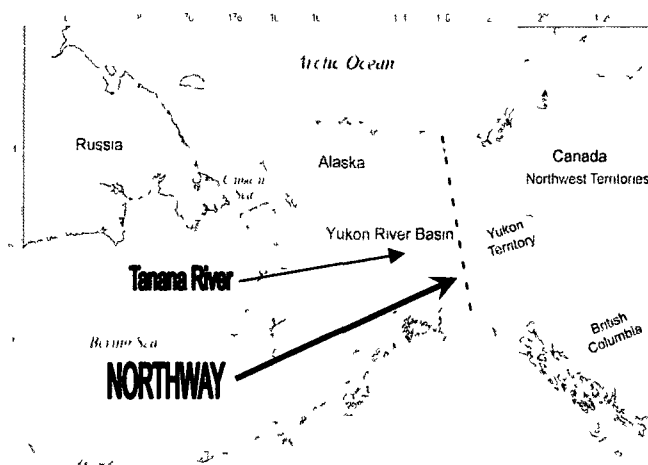
I thank multiple UAF entities for funding this project: the Resilience and Adaptation Program; the Center for Global Change; the James R. Crook Memorial Fund; and the Graduate School. The (former) Community Forestry and Environmental Research Partnership group at UC Berkeley provided significant funding and much energy to the project. Last but not least, I thank the Department of Chemistry and Biochemistry, which has been a wonderful academic base for over ten years.

## INTRODUCTION

The legacy of military waste is a pervasive concern for Alaska Natives throughout the state (1-5). The release of hazardous material under such programs as Lend Lease, White Alice, and the Distant Early Warning Line was extensive and has been mostly documented in hindsight (1). Nuclear weapons testing at Amchitka Island in the 1960s and 1971 (6) and uninformed experimentation on Alaska Natives in northern Alaska with radioactive iodine in the 1950s (7), as well as chemical and biological weapons testing (8, 9) and a leaky nuclear reactor (10) at Ft. Greeley in the Upper Tanana also contribute to the military's toxic legacy (11). The fact that many communities in Alaska have a Formerly Used Defense Site (FUDS) implies that the effects of militarization, including toxic waste, should be regularly included in discussions of community health and wellness. The small community of Northway, Alaska is one of many rural Alaskan communities affected by its military past. As elsewhere, the situation of environmental injustice is unique and highly complex

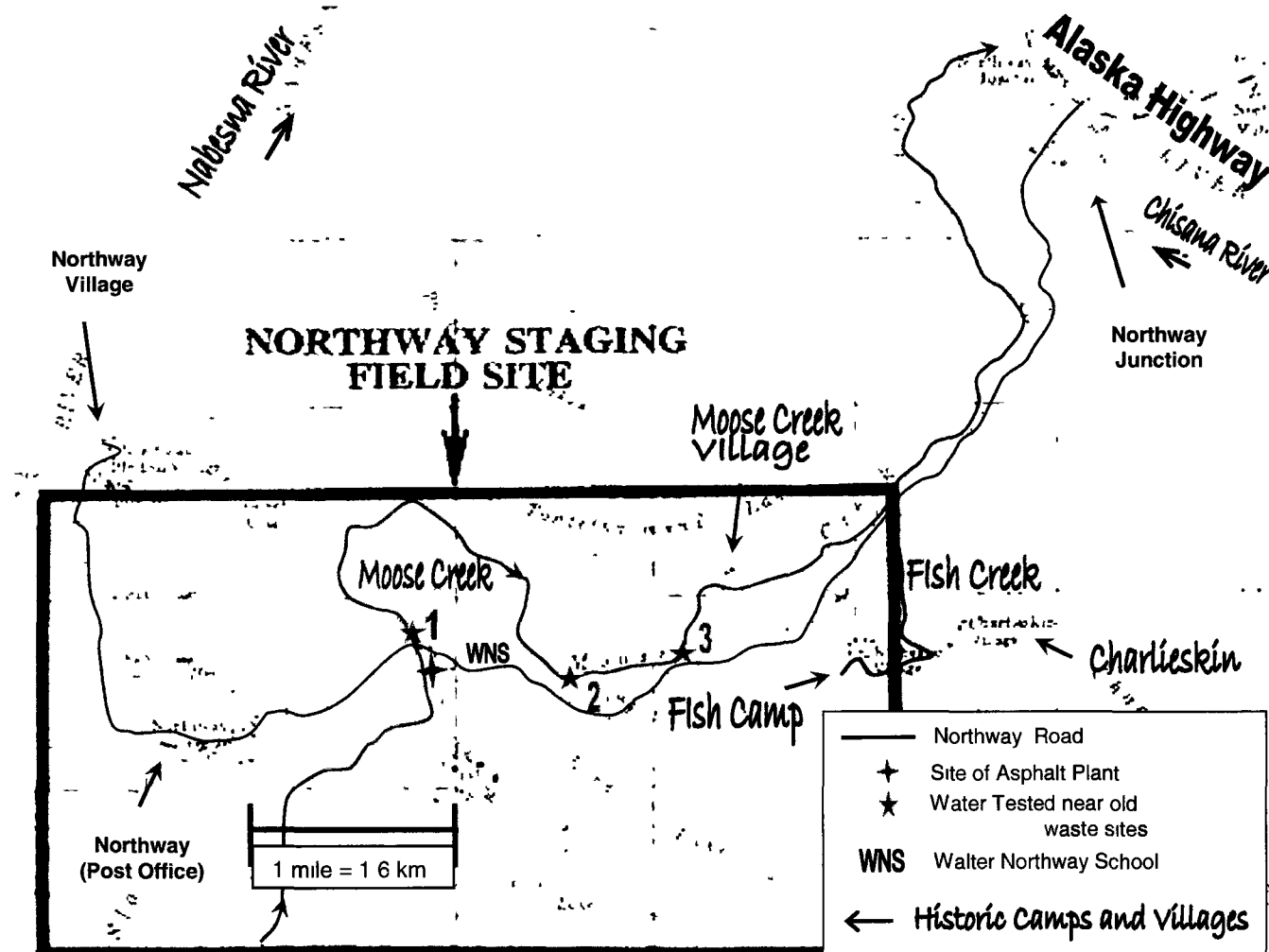
Northway is located along the Alaska Highway in the Upper Tanana River Valley of the Yukon River Watershed in Eastern Interior Alaska (Figure 1).

"Northway" (Figure 2) includes Northway Village, the airstrip area (Northway), Northway Junction, and some 60 miles of the Alaska Highway, with a census population estimate of 361 (14, 15) Construction in 1942



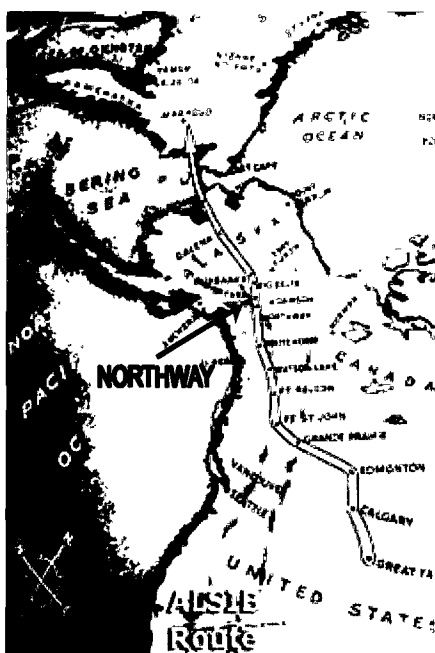
**Figure 1.** Northway Location Map. Adapted from (12).

of the Alaska-Canada (ALCAN) and Alaska-Siberia (ALSIB) Routes (Figure 3; also known together as the Northwest Staging Route) brought tremendous change to this region of Alaska. Northway was one of several communities impacted by the military activities. The "Northway Staging Field" was a major base and was polluted by various toxic materials, especially petroleum (Chapter 1).



**Figure 2** The Northway Staging Field Site and surrounding area. Water from the western portion of the airfield moves north to the Nabesna while the eastern end drains to Moose Creek, flowing east to the Chisana River. Those rivers become the Tanana just off the map Adapted from (13).





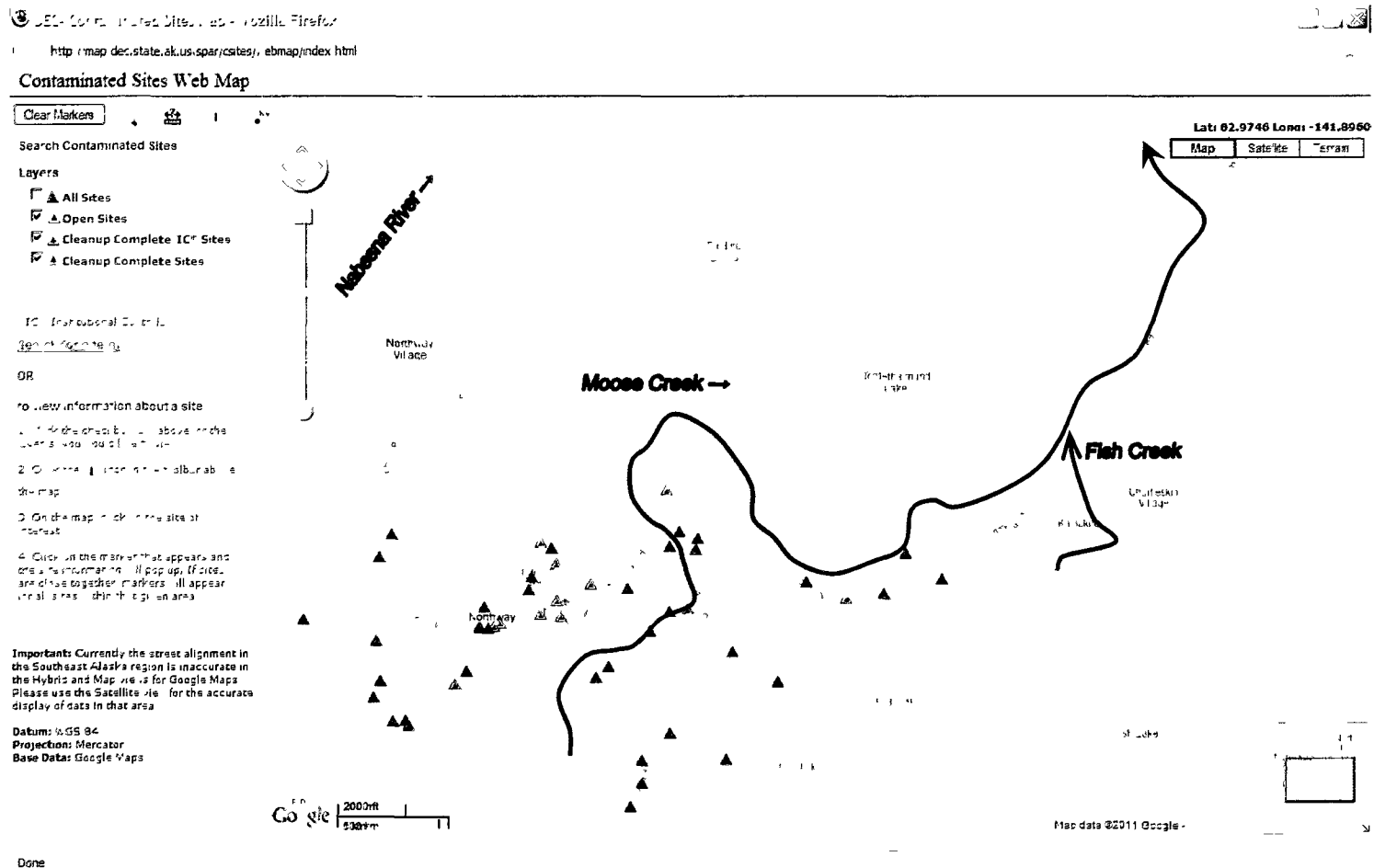
**Figure 3.** The Alaska-Siberia Route. From (16).

Fuel and petrochemicals like solvents, lubricants, and hydraulic fluids, as well as pesticides were widely used, including outside the Staging Field (17). Pesticide and herbicide application along Northway Road and the highway continued for decades (18). Oil pipelines that paralleled the highway, and feeder pipes along Northway Road, were active from 1944 to 1973. These pipelines often leaked and were sprayed with defoliants for aerial inspection and accessibility (19). Most of the contaminant sources were remediated in the 1990s, but waste sites were numerous, extensive, and had been left uncontained for up to 50 years.

Currently, the Alaska Department of Environmental Conservation (ADEC) Contaminated Sites Program database (20) lists 72 sites for

Northway (Figure 4). Of the sites, 42 were associated with the Northway Staging Field. Many were not recognized as military in origin and most of those have been remediated to various degrees by responsible parties such as the FAA, Department of Transportation (DOT), and private entities (20). Remedial investigation was initiated in the 1980s and clean-up was extensive. Most sites were remediated and closed by 2004 (22). Twenty six sites remain open, mostly for monitoring petroleum plumes. Ten of these are within the staging site, and some are due for closure (20). How much pollution there was 50 years ago will never be known.

Contamination remains and has important tangential effects. For example, an aircraft fueling station at the airstrip was acquired by the State of Alaska in 1971 and eventually sold to a private party. The combination motel, restaurant, bar, and fuel outlet was abandoned in 2010 due to contamination. The closure of the Airport Lodge adversely affects the local economy and perpetuates the impression of irresponsible government (23).



**Figure 4.** Contaminated Sites Web Map. The Alaska Department of Environmental Conservation Contaminated Sites Program Web Map of the Northway area, March 17, 2011. Blue tags mark closed sites and yellow tags mark open sites, some of which are due for closure. Adapted from (21); Moose Creek course is approximate.

Initial interviews in 2005 and 2006 revealed two essential questions: What is in our foods? and Why is there so much sickness? Answering these questions became the objective of the project, with clues provided by participants. While most concerns were vague, some were explicit. 'Moose Creek and cancer,' they said. 'Our fish... it seems like the people who eat wild foods are the ones who are sick. And what about that pipeline? We used to pick berries up there.' The results of those initial interviews were summarized in a letter to the initial informants in 2006 (Appendix A).

In order to distinguish between historic and contemporary risks, the Northway Wild Food and Health Project (NWFHP) included two main components: the Northway Wild Food Study (NWFS), to investigate current contaminant levels, and the Northway Health Study (NHS), to investigate possible associations among historic resource uses and health problems. While the two studies are necessarily distinct due to the long passage of time, they are also closely related. The inference that pollutants, which are implicated for similar health problems elsewhere, contributed to health problems among people exposed to them in Northway is reasonable. Exposure was not documented and cannot be quantified, but the general (yes or no) use of historic resources is remembered. Evidential strength of the historic pollution pathways that we identified varies from substantial to hearsay, while health associations are based on personal memories and subjective knowledge. The findings can be summarized as follows:

- ✱ use of Moose Creek, which was polluted with petroleum during and following the paving of the airfield in 1944, was associated with cancer;
- ✱ consumption of whitefish, which were polluted with persistent organic pollutants such as pesticides, was associated with thyroid problems and cancer (as well as negatively associated with cardiovascular disease);
- ✱ use of the Haines-Fairbanks Pipeline corridor, where the herbicide 2,4,5-T had been sprayed, for collecting various resources was associated with reproductive problems and cardiac irregularities, and, with less statistical strength, three metabolic disorders; and
- ✱ use of FAA water, described as "...nasty and heavily chlorinated (24)," was strongly associated with reproductive problems and at least weakly associated with all studied conditions in all datasets.

Remediation documents and the toxicological literature corroborate the findings of the health study (the analysis of local knowledge), making a strong circumstantial case for the validity of the findings. The effects of environmental contaminants are more likely to be subtle than hypothetical, which is demonstrated by the Northway Health Study. This introduction reviews the context and project development in Northway, ending with an overview of the chapters that detail the methods, results, and implications of local environmental health knowledge production in Northway.

### **The Natural Environment and Pre-War Context**

The Upper Tanana River region of eastern Alaska is made up of a valley floor dominated by wetlands, gradually rising toward Canada to the east. To the west, the river passes Tok, Delta, Fairbanks, and joins the Yukon River at Tanana. The hills of the Yukon-Tanana Uplift are close to the north, while the Wrangell-St Elias Mountain Range stands to the south. Northway is located near the confluence of the Nabesna and Chisana Rivers, where they become the Tanana River. At 550 meters above sea level, Northway is in one of the coldest regions of Alaska (25).

People of the Upper Tanana were semi-nomadic hunters and gatherers adapted to the extreme conditions of their environment over millennia. Whitefish were a primary source of nutrition, along with a variety of small game, including muskrat, snowshoe hare, beaver, “wild chicken” (grouse and ptarmigan), and waterfowl (26). Moose and caribou were also harvested. The rotation of seasonal camps and the perpetual preparation for winter kept people healthy late into life (26, 27). As Northway Elder Ada Gallen put it, “[o]ld people cut fish until they died (28).” Although various goods and epidemics preceded them, the first contact with Europeans was in 1898 when two starving prospectors were saved by the local Chief and his son, who were out hunting ducks (27). Years later the family and the village took the name Northway. The young man, Haa Ch’iinii’aa, lived until 1996, passing as Traditional Chief Walter Northway at 117 years of age (27).

Very early in the 20th century, “white foods” such as sugar, flour, and tea, were traded for skins and other goods, and carried by foot from Dawson, Yukon Territory during summer expeditions (27, 28). In the 1920s and ‘30s, American influence continued to increase, bringing church, school, merchants, and a strong fur trade.

Merchants and missionaries knew what was best from their cultural perspective: traditional ceremonies were discouraged and youth were denied access to their heritage with the barring of first language and decreased intergenerational time on the land (29).

Despite the changing context, the rhythm of the seasons continued and food procurement was still almost entirely from the land. During his field work in 1929-1930, anthropologist Robert McKennan wrote that “[a]ll in all the natives are a remarkably healthy people except for the devastating effects of tuberculosis and the high mortality rate among children caused by improper feeding [flour and sugar, which he mentioned earlier] (26).” Maury Smith, a journalist who traveled to Alaska in 1940 wrote of the Northway area “Nabesna Indians live probably the purest form of Native life of any in the territory, uninfluenced by white man’s habits (quoted in (30)).” Alcohol was “absent” as late as 1930 (26) and “rare” until the war (29). World War II foreshadowed rapid acceleration of social and environmental change across Alaska. For the previously isolated Upper Tanana, the war would bring a series of airstrips, and a road through Canada to connect military bases near Fairbanks to the United States mainland.

### **The Alaska-Siberia (ALSIB) Route**

One component of the US Lend Lease Program to support the Allies in WWII was the Alaska-Siberia (ALSIB) Route: a flight path for US aircraft lent to Russia for its fight against Germany (31). The massive projects would provide military access to defend Alaska and the North American continent. Recent publications about these developments often acknowledge effects on local populations, but at the time popular media focused on the war effort (32). Over eleven thousand troops were deployed and the remote ALSIB Route was established at lightning speed. The sudden development across a vast, remote stretch of the Pacific Northwest impacted local populations with dramatic and irreversible change that has been lightly documented (33, 34).

Airstrips were constructed before the road, and were quickly followed by a growing military presence to stage both the Alaska-Siberia (ALSIB) Route and construction of the Alaska-Canada (ALCAN) Route, now named the Alaska Highway. The road was not constructed from one end to the other, but from several points between, thereby requiring multiple staging areas. The Northway airfield and garrison were especially problematic. “Sixty degrees below zero was not unusual. Permanently

frozen ground, poor transportation facilities and inaccessibility of the site (by air only in winter) caused considerable delay (35)."

Beginning in September of 1942, Northway was a major refueling station along the ALSIB route for nearly 8000 flights to Russia over three years, especially in 1943 and 1944 (31). Fuel was supplied by barge (35) until the road opened in November of 1942 and tanker trucks added to the fuel supply. In February of 1944, the Fairbanks stem of the Canadian Oil Line (CANOL) pipeline system was opened (36) and the airfield was paved (35). "Feeder pipes" ran the 7 miles down from the main pipe to the Northway airfield (13). The Haines-Fairbanks Pipeline (HFP) replaced the failing CANOL in 1955, and was closed due to maintenance needs in 1973 (19).

While information referring to the purposes and timeline of construction is documented, most of what I have learned about Northway's particular history comes from interaction with local residents. The wealth of information provided to me by the initial interviews has been supplemented over the years by less formal conversations. Ada Gallen, Julius Sam, Darlene Northway, and Walter Mark have been especially generous with their memories and have contributed greatly to my perception of life in Northway since WWII. The remainder of this section reflects my understanding of relevant common knowledge among older adults in Northway, and has been reviewed for accuracy by members of the steering committee and other local residents, though some statements are also referenced to a particular person or an outside source.

Although the "Indian Village" and other sites were somewhat isolated from the military installation, food staples, alcohol, tobacco, petroleum hydrocarbons, and pesticides all became more common. Ancient trails were bulldozed, and burial sites desecrated. Women were vastly outnumbered by hundreds of soldiers and were often pursued, sometimes aggressively. The sudden military presence in Northway included land-use restrictions, ID cards, checkpoints, alcohol availability, racism, sexism, and toxic waste. The Army left the area at the end of WWII, but the airfield and FAA Station were active throughout the Cold War.

The Alaska Highway is among few military projects in its ongoing civilian utility. The ALCAN, while not designated as a whole, can be seen as a Formerly Used Defense Site. There were many staging areas, or "camps," along the route where fuel was transferred and insecticides were used to fight the relentless mosquitoes (17). The initial

“Pioneer Trail” was hastily cleared in nine months and improved over two years to a civilian road (36). Spills and other releases were inevitable and not always documented (37). The constant need for highway repair continues to this day, perpetuating a demand for the development of local services (34).

The full range of impacts resulting from the construction and maintenance of the highway (29, 33) is beyond the scope of this project, but it can be said that a decades-long, multi-faceted cultural transformation occurred as the road was opened to civilians, local residents acquired cars, and through-traffic grew. Since the war, myriad socio-cultural events, including boarding schools, acculturation to the wage economy, and the advent of processed foods, have further contributed to changing demographics, land-use patterns, and, ultimately, health (38). Opinions regarding the benefit and detriment from these events are mixed, even for individuals. Ada Gallen has told me more than once, without blame, that “White people ruined everything.” When asked how it seemed at the time, she said “It was new, it was different—we liked that. We didn’t know (28).” Across the Upper Tanana “Natives from Nabesna [Northway] to Tanana Crossing [Tanacross] supported the US Army building the international highway (30).” Integration was natural and several families in Northway are mixed race.

Northway’s location on the road system (80 km (50 miles) from Tok and 435 km (270 miles) from Fairbanks) provides easier access to large grocery stores than most communities in rural Alaska. The use of store bought food accelerated in the 1970s (Appendix A). Store bought food brought a measure of security to an area where collecting and preparing sufficient food had always been a tremendous amount of work (described elsewhere (39)). As residents adapted to these new sources of food, they were less likely to use the land to meet their needs. The ready availability of alcohol took a heavy toll on the community and contributed to related losses of traditional knowledge (Appendix A).

By the 1980s, concern about toxic waste became widespread due to an increased incidence of cancer. While the Village Council pushed for remedial action, wild foods were consumed but their use continued to decline. Stores and wage employment were locally described as primary drivers of the shift in dominance from a wild-based food system to a more market-based food system. However, related concerns do influence food choice, as documented for Northway in Appendix A.

Several deaths in the 1950s and 1960s were suspected in retrospect of having been caused by cancer, but they were neither diagnosed nor autopsied. One early diagnosis reported to the Northway Health Study was a man who had been employed spraying herbicides along the side of the highway in his early 30s (40), and who died of leukemia at 39 years old in 1971. His wife, who had lived with him along Moose Creek, died of leukemia in 2009. Her diagnosis was yet another indication to residents that it was something the couple were exposed to, rather than something genetic (41). In the 1970s more diagnosed cases increased concern, supported with stories told by family and friends across the Canadian border regarding the links between military sites and cancer. Suspicions remained guarded until the 1980s, as people did not want to accept what they were coming to believe. Major remediation finally occurred in the 1990s (42), after Northway Natives Incorporated produced "Pollution," a short film describing the toxic waste sites and cancer deaths (43).

### **Clean Up and Lingering Concerns**

Northway residents fought hard to obtain a ranking on the National Priorities List (NPL), which provided "Superfund" status and eligibility for clean up under the Comprehensive Environmental Response, Compensation, and Liability Act (44). The Northway Field Staging Area was investigated in the late 1980s and portions of the site were listed on the NPL in 1993 (45). Although many of the 52 "Potential Contamination Source Areas" documented by the remedial investigation did not identify chemical hazards, hundreds of tons of debris and thousands of yards of soil were removed in the mid-1990s (42). (Soil was burned and redistributed.) The 13 volume Administrative Record of investigation and remediation of the Northway Staging Field documents the extensive efforts made by the US Army Corps of Engineers Alaska District (USACE-AK), the Alaska Department of Environmental Conservation (ADEC), and their contractors, to remediate the area and inform residents of progress (46).

A 1991 memo between ADEC personnel before the clean-up is among the most straightforward documents in the Administrative Record (45). The memo, without an identified author, reviewed limited data (also reviewed below) regarding the detection of DDT (dichlorodiphenyltrichloroethane) and metabolites in samples of Northern Pike (*Esox lucius*) from Moose Creek. The task of informing residents "...about the DDT,



though in such a way so as to not alarm them” was raised and it was observed that none of the agencies involved with the investigation had established formal dialogue with the Village Council. With regard to contaminants, the document reads in part:

I seriously doubt if DDT is the only contaminant of concern in Northway. New dump sites are being discovered yearly as they surface and are found near and around homes. A school is also located within a mile of all the known dump sites. DDT, at whatever levels once present has long since been widely dispersed by erosion, runoff, and volatilization and entered the ecosystems (47).

Meeting notes from the mid-1990s, after formal dialogue had been established, document an official willingness to listen to observations and concerns (46). Much of the investigation and subsequent remediation was based on information from local residents about suspected sites. More troubling questions were, however, consistently dismissed. Airport muskrat were identified as the only “possibly significant” pathway by the remedial investigation and risk equations (13). Like other potential pathways, the possibility that such exposure could have caused harm was rejected—in part because of several unknowns (46). All personnel could do, 50 years later, was compare findings to allowable limits, and try to make sure contaminant levels were below those known to harm human health. However, some of the notes indicate evasion, such as the following from meetings held in 1995:

March 7

There were concerns raised about Moose Creek and the fact that several elders who lived on fish from Moose Creek had cancer. It was also noted that vegetation hasn’t regrown in areas where military sites had been.

Dames and Moore [remediation contractors, DM] explained that Moose Creek had shown some diesel range organics (DRO). DRO can occur naturally from decaying plants and is not listed as a carcinogen.

Vegetation can be very slow to grow back when the shallow permafrost has been disturbed or thawed.

June 26

The villagers will continue their subsistence lifestyle, and they want to know that these foods are safe. [Northway Village Council] Staff suggested the Alaska District [USACE-AK] could help fund a study by TCC or someone else on fish contamination. The residents could catch the fish but would need help with the analysis.

[DM] stated that fish had not been tested because no problem was found with the water in Moose Creek, but the [US Fish and Wildlife Service] fish data from Moose Creek was included in the risk analysis. No problems were identified. There was one low hit out of 20 samples. [0.11 µg/g; detection limit 0.01 µg/g (48)] The low hit was DDT, but DDT is not a human carcinogen, it's more of a problem for birds (46).

It is noteworthy that no Alaska Department of Environmental Conservation personnel are listed among attendants at the meetings (46). While the carcinogenicity of DDT had not been proven, it was suspected (49) and the pesticide had certainly been known as toxic to humans since well before 1995 (50). The ADEC Contaminated Sites Program (CSP) website provides a 2010 update of the situation:

The toxicity, volume, and mobility of contaminants have been reduced by removal of the primary sources of contamination (i.e. the drums, debris or contaminated soil). Specifically, confirmation sampling has verified that applicable cleanup levels have been achieved. Confirmation sample results provide assurance that the sites no longer pose an unacceptable threat to human health or the environment (20).

This comment is among few stated acknowledgments that prior threats to human health were unacceptable. Resident concerns regarding ecological exposures and

illness are still dismissively explained by tobacco, alcohol, and other unhealthy behaviors with no acknowledgement that toxic waste has been part of the system. One standard implication is that the only real health risks are presented by tobacco, alcohol, and the abandonment of traditional foods (51, 52). For example, in 2006 former Northway resident Larry Demit contacted the Alaska Native Tribal Health Consortium with concerns about cancer. In the response letter, the epidemiologist reviewed selected Alaska Native cancer data, pointed to increased cancer across the region, and simply ignored the history of toxic waste:

From this small sample of communities, one can see where as the size of the community doubles, the number of cancers on average doubled. The communities for which you expressed concern appear to have an incidence of cancer similar to other communities of the same size. A community with a higher proportion of persons over the age of 50 would be expected to have more cancer than a community with fewer elders.

Alaska Natives should be concerned about cancer. Community leaders play an important role in promoting cancer education including information on quitting tobacco, screening for colon/rectum, breast, cervix, and prostate cancers, as well as promoting healthy lifestyles, good diet and exercise (53).

I received a copy of this letter after inquiring to the State of Alaska Cancer Registry about Northway, and was left with the impression that talking to Northway residents would be a faster route to acquiring data. The Department of Public Health Division of Epidemiology is right to be concerned with confidentiality in small communities, but my experience implies their concern exceeds that of communities. I will never forget Mr. Demit's frustrated response when I called to talk about the letter: "You mean somebody cares? (54)"

Dismissal of perceptions about environmental pollution based on common personal observations does little to ameliorate suspicion and leaves the public distrustful and confused. Given the similarity of concerns (cancer, reproductive and thyroid

problems, etc.) to effects found in the toxicological literature such perceptions should be taken as observations that justify investigation, rather than dismissed. More than advice, people in Northway wanted information.

### **Complexity and Inferential Knowledge**

Complex biological systems from the cell to the biosphere are threatened by a dominant paradigm of risk management that waits for proof of harm. Epidemiology and Tort Law cannot be expected to protect people from environmental injuries. By their nature, these costly mechanisms of research and litigation are initiated after harm occurs and protection, per se, is no longer possible. Even with the power of large population studies, relationships that now seem obvious, such as smoking and cancer, require excessive evidence before they are considered “proven.” Systemic capacity to address undocumented historical exposure to involuntary risks is even more limited, as the thesis clearly demonstrates.

Phenomena such as environmental contaminants, diet, addiction, and globalization interact with health in highly complex ways for correspondingly complex outcomes (55). These interactions do not follow a predictable timetable, and cannot be identified quickly or quantified with certainty. Undocumented historic conditions make research even more challenging. Although the value of retrospective environmental science can be very high, 95% certainty is rare (56). Meanwhile, toxicological literature from laboratory experiments on well-developed animal models of human physiology demonstrate that chronic low-level exposure to multiple endocrine disruptors is likely to have detrimental, but not clear-cut, effects on human health and wellness (57-60). Though inevitable, this lack of clarity and certainty seems to partially explain why related research in small populations is rare. However, ignoring the situations will neither alleviate nor help clarify them.

### **The Northway Wild Food and Health Project**

The Northway Wild Food and Health Project (NWFHP) began as an informal proposal of contaminants research to then President of the Northway Village Council, Gerald Albert, in 2004. Robert Lee Demit, a former Northway resident, had told me that Mr. Albert was very concerned about contaminants (Feb 24, 2004). Mr. Albert welcomed the prospect of a study that would address local concerns regarding food safety and, once the project started in 2005, gave me a local phone list. Many names were highlighted as people that I should call and visit to survey for questions and priorities for a study.

Anthropological and community driven approaches to health research had been applied elsewhere (61, 62), and seemed, as expected, the most appropriate way to address ongoing concerns. Although the project was not an intentional application of the Community Based Participatory Research (CBPR) paradigm, it made sense to include local knowledge in the establishment of research questions, the design of the studies, the collection of data, and the interpretation and dissemination of results, as espoused by the CBPR model (63). This approach was a natural way to develop research that would integrate local observations and scientific literature, and residents were receptive. The increasing popularity of CBPR methods was evident in the literature as the project developed and provided examples (64-68) and encouragement. Given the long historical context, and the observational capacity of local residents to witness and remember events that are otherwise not documented, local involvement was critical.

Community interest was high, although barriers such as distrust and time constraints were significant. I quickly came to realize that the distrust had little to do with me, but rather reflected decades of frustration over these and other (69) issues, including a general distrust of outsiders, especially white researchers (27). Informants were guarded, but eager to share their questions, observations, and suspicions once they knew I was listening. The University showed some institutional reluctance to relinquish control over research and make commitments based on the intentions one graduate student, with a strong preference for a Memorandum of Understanding rather than a Partnership Agreement. It may have been largely symbolic, but it was important that Northway leaders and residents understood that I would need their help as the project moved forward and that I would not make major decisions without their input. A

partnership agreement was established (Appendix B) and the work continued under mostly informal guidance. The most significant barriers were financial. Funding to sufficiently evaluate the safety of Northway's wild foods was never acquired, but limited results support the general notion (52) that wild foods are currently healthy and at least as safe or safer than many store bought processed foods (Chapter 1).

It was clear very early in the initial interviews that a survey of contaminant levels in a few important traditional foods would not adequately address concerns: a health study was locally desired. Every informant named cancer as their main cause of concern, while many named other health conditions they thought were related: thyroid problems, learning disabilities, autoimmune disease, and reproductive problems. The years it took to conduct the limited study of contaminants in wild foods were critical for the development of a feasible and credible health study that would be widely supported. Our study began with particular attention to cancer, thyroid and reproductive problems, and diabetes, and expanded to include cardiac irregularities, as well as high blood pressure and high (LDL) cholesterol.

This statistical analysis of Northway's collective knowledge supports suspicions and validates general concerns regarding the toxic effects of military waste. However, such evidence is historic and necessarily circumstantial. The situation will never be measured or documented as it took place. The inferences made here are well supported in the toxicological literature, and the probability that they are real is high, despite the lack of definitive "proof." Even extensive research would leave room for doubt.

This project was discouraged by National Institutes of Health (NIH) peer-reviewers and state epidemiologists due to the small population size and the sensitivity of the issues. Many factors perpetuate the avoidance of related research. If responsibility is defined as the ability to respond, and the State of Alaska's options are limited by a federal system that is not designed to address these situations (70), the commissioners of state agencies are in an awkward position. Nonetheless, as shown here, local knowledge provides important insights to the complex etiology of disease. Many communities in Alaska would benefit from historically contextual research that begins with local health concerns and observations, especially those with a legacy of toxic waste.

## Chapter Overview

As mentioned earlier the Northway Wild Food and Health Project began with a survey of a few contaminants in a limited number of traditional foods locally suspected of contamination (whitefish, muskrat, edible roots, and snowshoe hair). Samples were collected from both near and away from the road. Chapter 1 provides a descriptive review of biological sampling data in the Northway area, including the samples we collected for the Wild Food Study as well as studies conducted by the US Fish and Wildlife Service that operates the Tetlin National Wildlife Refuge surrounding Northway. The chapter also includes a discussion of moose, albeit abstract, and a brief mention of water. Although moose are currently the primary source of wild protein in Northway, they were rarely mentioned as suspected carriers of contamination and data are available from only one sample that was collected over one hundred miles away. Water safety was mostly beyond the scope of this project despite concerns raised regarding several of Northway's historic and current water supplies (71).

Whitefish and edible roots ("Indian Potato") were and are still used, and people wanted to know about airport muskrat, making these the priority species. While samples collected near the road had higher levels of contaminants, more samples, from multiple locations would be needed to establish averages and statistical comparisons for any particular species. Nutritional analysis faced similar obstacles. We could not compare the nutritional value of foods based on contaminant levels, but did affirm important nutritional benefits of local whitefish and roots.

Results of the Northway Health Study (NHS) are described in Chapters 2, and discussed in Chapters 3 and 4. Chapter 3 is focused on Moose Creek water and an apparent relationship with cancer, as well as fish, which were significantly associated with thyroid problems and cancer, and at least weakly associated with other problems. Chapter 4 is focused on a higher reported incidence of several health problems among users of the Haines-Fairbanks Pipeline corridor compared to non-users. Chapter 5 frames the project as a case study of low-level population-wide exposure to a variety of endocrine disrupting chemicals via poorly documented, confounded, and complex pathways. The chapter ties the previous chapters together with a more complete look at the uncertainty surrounding the effects of environmental exposure to contaminants.

While Chapters 3 and 4 discuss the strongest results, Chapter 5 addresses the multiple confounders of a historic study like the Northway Health Study, and the inability to elucidate clear “cause and effect” relationships. This is partly due to a lack of medical and biochemical detail, but is mostly a result of the deep complexity of cellular mechanisms that govern health. A model of the actual weight of various historically contaminated resources toward health outcomes would necessarily include additional risk factors, and would require more complex statistics and a larger study population. However, large scale studies face similar challenges (72). Chapter 5 finds that attention to individual and collective local knowledge of a relatively isolated complex system can deliver important insight regarding environmental health and historical toxic effects of unquantifiable chronic low-dose exposures. Two key points are that a lack of historic documentation neither demonstrates an absence of effects, nor prevents the collection and reasonable interpretation of available evidence.

Chapter 6 is focused on confronting the injustice of the situation with local knowledge production. No one I spoke to in Northway believes the contamination was intentional. However, they want to understand what happened and to make informed decisions and have the right to do so. Chapter 6 suggests that the integration of local and scientific knowledge systems regarding food safety and security could be an important step toward environmental health and justice in rural Alaska.



## **1. THE NORTHWAY WILD FOOD STUDY: CONTAMINANTS AND NUTRITION NEAR THE NORTHWAY STAGING FIELD AREA**

### **Introduction**

Wild foods have provided excellent nutrition in the Upper Tanana region for thousands of years, enabling a complex society to develop despite the extreme conditions of Interior Alaska. However, concern over contamination of wild foods is pervasive in Northway and the purpose of the Northway Wild Food Study (NWFS) was to answer the general question raised during initial interviews: "What is in our foods?" Those interviews, with elders and other regular resource users, enabled the prioritization of wild foods and locations for testing, while review of remediation documentation and toxicological literature contributed to the choice of chemical analytes. Limited samples of select wild foods including fish, muskrat, and edible roots picked along roadsides, were surveyed for metals, PCBs, and nutritional value. If it were not for Northway's proximity to the Tetlin National Wildlife Refuge, there would be no biological contaminants data prior to this study.

As nutritional and other benefits were never in question, contamination remains the primary focus. Samples were donated by local residents or collected by the author with assistance. All were tested by certified labs with Environmental Protection Agency recommended methods. Low levels of contaminants were detected in most samples tested. All findings were below regulatory guidelines of concern, but generally increased with road proximity and trophic level. The study supports the idea that the nutritional benefits of wild foods are high, especially compared to many of the store bought foods that commonly replace them (52). In addition, the health risks of commercially produced and processed foods, which include low levels of many of the same persistent organic pollutants as found in wild foods, as well as hormones, antibiotics, and newer pesticides, are similarly unknown (73, 74).

Food procurement in the Upper Tanana region has changed dramatically over the last century, especially the last 40 years (Appendix A). Prior to WW II, whitefish were a primary source of protein, supplemented by many species of small game, such as muskrat, beaver, snowshoe hare, grouse, ptarmigan, and waterfowl, as well as moose and caribou. Wild plants from roots to berries were also important for nutritional,

medicinal, and cultural purposes (26). The food system began to change slowly with the gold rush of 1898, when limited food staples came to the area with miners, missionaries, and merchants. However, because there was little accessible gold in the Upper Tanana River Region, the area was somewhat isolated until WWII related activity began.

The military construction changed life in the area dramatically, especially after the road opened to civilians and local residents acquired vehicles. Since then, Northway has shifted from a wild food-based system toward a market-based economy where wild foods often provide the protein for meals that are supplemented by store bought foods. Northway's road access to large cities makes groceries more easily available than in most rural Alaskan communities (435 km (270 miles) to Fairbanks) (39, 75). However, transportation costs for these foods are still high and access to fresh, high quality, whole-foods is limited. Although the frequency and variety of wild food use has declined for several reasons, many families in Northway continue to take much of their nutrition from the land and waters (Appendix A). The harvest of wild foods, especially moose and whitefish, is important to the local economy, in savings and in costs (i.e., fuel and time).

Northway residents have long been suspicious of toxic exposure because of multiple cancer deaths and other health problems, but no study has carefully evaluated the permeation of waste into the local food web. The depth of influence that perceptions have had on other related phenomena, especially transgenerational knowledge transmission, remains unknown. Young adults are drawn away from traditional practices by many forces, but often indicated that they would be more interested in acquiring traditional knowledge and skills if they trusted the foods.

The irony, as elsewhere, is that available alternative foods tend to be processed and offer lower nutritional value than wild foods. Further, many physical and social benefits are lost as traditional foods are given up, such as outdoor exercise and the support of food sharing networks (38, 76). Northway residents have a profound awareness of the dilemma (76) and strongly desire more information about the details in order to assess the current situation themselves. Beyond the practicality of informed decisions, people in Northway have a right to know what kinds of contaminants are in their foods (77). This review affirms that military and other environmental contaminants entered the local food web and identifies several pathways of human exposure that were inevitably more substantial during decades past.

## Design and Methods

The Northway Wild Food Study (NWFS) study employed a qualitative, mixed methods approach to documenting contaminant levels in Northway's wild foods. During the summer of 2005, 24 interviews were conducted with individuals and couples (total of 36 people), beginning with elders, but including other regular users of the land. Species were prioritized for testing by how many people named them (listed in Appendix A). Sampling sites were based on local suspicions as well as remedial documents. More species were named than could be tested because of funding limitations and few samples were analyzed. Contaminant priorities were based on remedial documents and the general rules of fate and transport regarding the uptake of contaminants into particular species.

The main military site at Northway was the airfield (the Northway Staging Field, Figure 2), where petroleum was the main source of contamination. There were many above and below ground fuel tanks and multiple fueling stations, as well as barracks, airplane hangers, and machine shops between and around the airstrip apron and Moose Creek (20, 71). Water from the apron and western portion of the airstrip moves north, toward Northway Village, while the east end of the airfield drains to Moose Creek, which moves east through or past several old waste sites (Figure 4). Open tar pits and other waste sat near Moose Creek for decades after construction of the airstrip, although the asphalt plant had been demolished by the mid 1950s (78).

Foods were not tested for polycyclic aromatic hydrocarbons (PAHs) because of the low likelihood that they would be present in species such as fish, which are known to metabolize these compounds rapidly. The presence of dichlorodiphenyltrichloroethane (DDT) and metabolites had been documented in soil and fish from Moose Creek. Polychlorinated biphenyls (PCBs) had not been detected on military properties, but there was at least one leaky transformer at the Federal Aviation Administration (FAA) facility (79). PCBs are highly toxic and common fish contaminants, often as a result of federal activity (80), and were chosen as the persistent organic priority. Although berry picking in the Haines-Fairbanks Pipeline corridor (where herbicides including 2,4,5-T were used; Chapter 4) had been very popular, dioxin levels were not tested because of funding constraints. It was also unlikely that hydrophobic contaminants would be found in the raspberries (81).

The samples of whitefish, airport muskrat, and edible root were collected fresh. Muscle tissue was cut, packaged in glass jars (fish with skin), and frozen in a household freezer within a few hours of being caught or shot. These samples were kept frozen en route to Fairbanks, where they, and all remaining samples, were frozen to -70° C pending overnight shipment for analysis. Edible root samples were collected in plastic bags, sealed, kept cold, and taken to the chemistry lab where they were rinsed with deionized water, put in clean plastic bags, and frozen. Snowshoe hare samples were donated whole and frozen. The samples were thawed, skinned, cut, bagged and refrozen. Other donated muscle samples (upriver muskrat and beaver) were frozen in plastic and of appropriate size for analysis. They were kept frozen pending shipment. All samples (2 whitefish, 4 muskrat, 5 snowshoe hare, 1 beaver, and 13 edible root) were analyzed for individual metals\* and total heavy metals (Sum of antimony (Sb), arsenic (As\*), bismuth (Bi), cadmium (Cd\*), copper (Cu), lead (Pb\*), mercury (Hg\*), molybdenum (Mo), silver (Ag), and tin (Sn)), with the methods and detection limits outlined in Table 1. One sample each of whitefish and muskrat were analyzed for PCBs (12 dioxin-like congeners, as well as total PCBs).

<b>Table 1. Methods and detection limits for metals. Analyses were conducted by Midwest Laboratories, Inc, in Omaha Nebraska.</b>		
<b>Metal</b>	<b>Method</b>	<b>Detection Limit (µg/g)</b>
Mercury (Hg)	Cold Vapor	0.02
Lead (Pb)	ICP-MS	0.1 to 5.0
Cadmium (Cd)	ICP-MS	0.05
Arsenic (As)	ICP-MS	0.5
Total Heavy Metals	ICP/ICP-MS	10

Semi-permeable membrane devices (SPMDs) were used to test Moose Creek water for 18 PAHs in three locations downstream from the airstrip adjacent to native allotments with remediated waste sites (Figure 2). The SPMDs were provided by Environmental Sampling Technologies (EST), St. Joseph, MO. The devices were secured in the water column 60-90cm below the surface and a similar distance from the edge of the steep-walled creek, and left in place for 27 days to adsorb lipophilic

contaminants. Upon removal from the water the membrane devices were frozen in their containers. They were shipped from Fairbanks to EST where the membranes were extracted by dialysis, cleaned up for analysis (detailed methods in following block quote), and shipped to Columbia Analytical Services, Inc (Kelso, WA) where the dialysates were analyzed by EPA Method 8270C – SIM.

These samples were received at EST on 23 September in a cooler with ice, and were put into dialysis the same day. Following dialysis the samples were concentrated using Kuderna-Danish and the two SPMDs that comprise the sample were combined during this phase. The dialysate was then blown down to a volume of about 0.5mL under UHP nitrogen gas (AirGas) and filtered through glass fiber filter paper (Fisher, G-6) using GPC mobile phase (Methylene Chloride, EMD Lot 49105 +2% Methanol, EMD Lot 49107) as the transfer solvent. The samples were blown down again to about 0.5mL and quantitatively transferred to two auto sampler vials per sample. They underwent GPC clean up on 28 Sept. Following the cleanup the dialysates were recombined, blown down and transferred to hexane as the transfer solvent. The ampules were chilled in a dry ice/ IPA solution and sealed with an oxygen / acetylene torch. There have been no surrogates of PRCs added to the sample. The volume in the ampule is unknown and may contain traces of mobile phase from the GPC cleanup. Do not use an aliquot without first establishing a known total volume (82).

## **Results**

### ***Contaminant Levels***

All biological tissue contaminant results are reported in Tables 2 and 3. Lead was found in all samples taken near the road system, except whitefish. Away from the road system, the only metal detected was Cd in the root sample from along the Chisana River. The only metal detected in whitefish was total mercury (Hg). PCBs were found in both the whitefish and the muskrat sample, dominated by non-dioxin-like congeners with 5-7 chlorine substituents. Moose Creek water average results of 1.14 µg reflect the total

**Table 2.** PCBs in whitefish and muskrat. Total PCBs (wet weight).

Congener specific data listed in Table 4a. Analyses were conducted by Pacific Rim Laboratories Inc., Surrey, B.C..

Species	n	$\Sigma$ PCBs (ng/g)
Moose Creek Whitefish	1	0.246 (average of duplicates)
Airport Muskrat	1	1.21

**Table 3.** Heavy metals in tested species. Laboratory methods of analysis, and detection limits can be found in Table 1.

Species	n	Pb ( $\mu\text{g/g}$ )	Hg ( $\mu\text{g/g}$ )	Total metals <sup>a</sup> [other] ( $\mu\text{g/g}$ )
Whitefish	1	nd	0.15	nd
Whitefish	1	nd	0.06	nd
Airport Muskrat	1	30.0	nd in muscle 0.05 in fur	>30
Airport Muskrat	1	0.11	nd	nd
Upriver Muskrat	2	nd	nd	nd
Roadside SS Hare	2	5.9 and 11.4	nd	nd
Roadside SS Hare	3	nd	nd	nd
Roadside Root	1	26	nd	37 [0.52 As]
Roadside Root	4	0.17-0.88	nd	12-14
Roadside Root	7	0.12 - 0.38	nd	nd
Upriver Root	1	nd	nd	nd [0.26 Cd]
Upriver Beaver	1	nd	nd	nd

"nd" = non-detect; data reflect wet weight concentration. <sup>a</sup>Sum of antimony (Sb), arsenic (As), bismuth (Bi), cadmium (Cd), copper (Cu), lead (Pb), mercury (Hg), molybdenum (Mo), silver (Ag), and tin (Sn).

mass of 18 PAHs adsorbed to the devices during 27 days in the water. Congener specific data for the PCB and PAH findings are reported in Table 4.

### ***Nutritional Values***

Laboratory analysis affirmed the high nutritional value of whitefish and roots. Nutritional data for raw, boiled, half-smoked and fried (in vegetable oil), and smoked-dry whitefish (average of two samples each), and one sample of edible root, are included in Table 5. Along with these local wild foods, the table lists the nutritional values for canned tuna fish, frozen fish sticks, boiled potatoes, and potato chips as well as select available contaminant levels. The examples demonstrate the general rule that local wild foods provide excellent nutrition (particularly in terms of fat quality and micro-nutrient content), while whole foods from the grocery store are a next best choice. Heavy processing produces the least nutritious food and is often not just empty, but unhealthy. Processed foods are often the least expensive, a problem that is not unique to rural Alaska (83). The loss of nutritional benefits are an important part of the risk versus benefit equation that must be considered when changing dietary patterns are evaluated (84, 85).

### **Discussion**

There is a general assumption in Alaska that wild foods are superior to store foods (86). Much of the justification for this sweeping assumption comes from the fact that the natural environment of Alaska has long provided the nutritional sustenance required for robust health (52, 87), and remains somewhat isolated from the great bulk of industrial pollution, despite the vulnerability of the Arctic marine food web to global sources of persistent organics and mercury (88, 89). Additionally, Alaskan grocery stores are far from major zones of agricultural production and most food is shipped very long distances. Transportation to rural villages often includes multiple small stages and threats of temperature extremes. "Store food" (also known in Northway as "white-" or "lazy-food;" Appendix A) that is shipped to rural Alaska tends to be highly processed for durability (39). While nutrition of these imported foods is limited, packaging that becomes trash, abounds. The toxicity of some of that packaging (90), such as plastic lined cans (91, 92) is another issue to consider, but beyond the scope of this project. Limited contaminant data for tuna fish is presented in Table 5.

<b>Table 4a.</b> Congener specific data for PCBs in muskrat and whitefish. Data reflect ng/g, wet weight concentrations. Muskrat taken from Heudec Lake, just north of the airstrip apron (n = 1); whitefish taken from Moose Creek at the confluence with Fish Creek (Figure 2).				
<b>Detected dioxin-like PCB congeners</b>	<b>Detection limit</b>	<b>Airport muskrat</b>	<b>Whitefish (dup. of same fish)</b>	
PCB 118 (2,3',4,4',5 PeCB)	0.005	0.02	0.011	0.019
PCB 105 (2,3,3',4,4'-PeCB)	0.003	ND	0.004	0.006
PCB 167 (2,3',4,4',5,5' PeCB)	0.003	0.003	ND	ND
PCB 156 (2,3,3',4,4',5 PeCB)	0.003	0.014	ND	ND
PCB 167 (2,3',4,4',5 PeCB)	0.003	0.004	ND	ND
WHO TEQ: ND = 0		9.19 E-6	1.44 E-6	2.56 E-6
WHO TEQ: ND = Detection Limit (DL)		3.43 E-4	3.37 E-4	3.38 E-04
<b>Total Homologs (ng/g)</b>	<b>Detection Limit</b>	<b>Airport Muskrat</b>	<b>Whitefish</b>	
Monochlorobiphenyls	0.005	0.008	0.006	ND
Dichlorobiphenyls	0.005	0.008	ND	0.005
Trichlorobiphenyls	0.01	ND	ND	0.012
Tetrachlorobiphenyls	0.01	0.012	0.022	0.028
Pentachlorobiphenyls	0.01	0.055	0.06	0.103
Hexachlorobiphenyls	0.01	0.448	0.071	0.133
Heptachlorobiphenyls	0.01	0.514	0.02	0.033
Octachlorobiphenyls	0.01	0.14	ND	ND
Nonachlorobiphenyls	0.005	0.018	ND	ND
Decachlorobiphenyl	0.002	0.009	ND	ND
<b>Total PCB</b>		<b>1.21</b>	<b>0.179</b>	<b>0.314</b>



<b>Table 4b. Congener specific data for PAHs in Moose Creek (µg/27 days). Locations in Figure 2.</b>				
<b>Congener (µg/g)</b>	<b>Location 1</b>	<b>Location 2</b>	<b>Location 3</b>	<b>Average</b>
Naphthalene	0.140	0.140	0.130	0.137
2-Methylnaphthalene	0.180	0.210	0.180	0.190
Acenaphthylene	0.011	0.010	0.009	0.010
Acenaphthene	0.062	0.053	0.053	0.056
Dibenzofuran	0.098	0.085	0.091	0.091
Fluorene	0.081	0.070	0.076	0.076
Phenanthrene	0.310	0.270	0.290	0.290
Anthracene	0.042	0.012	0.016	0.023
Fluoranthene	0.130	0.110	0.130	0.123
Pyrene	0.067	0.047	0.056	0.057
Benz(a)anthracene	0.029	0.003	0.005	0.012
Chrysene	0.025	0.006	0.007	0.012
Benzo(b)fluoranthene	0.033	0.003	0.004	0.014
Benzo(k)fluoranthene	0.040	ND	0.002	0.021
Benzo(a)pyrene	0.027	0.001	0.002	0.010
Indeno(1,2,3-cd)pyrene	0.030	0.001	0.002	0.011
Dibenz(a,h)anthracene	0.024	ND	0.002	0.013
Benzo(g,h,i)perylene	0.023	0.001	0.002	0.009
Total	1.352	1.023	1.056	1.144

Table 5. Nutrition data for canned tuna, fish sticks, Northway whitefish, and "potatoes." Contaminants data if available.										
/100 g	US Tuna fish in water <sup>a</sup>		Fish Sticks <sup>a</sup>	Northway whitefish <sup>b</sup>				"Potatoes" <sup>a,b</sup>		
	light (93)	white (94)	(frozen) (95)	raw	boiled	1/2 smkd	smkd dry	"roots"	boiled (96)	chips (97)
moisture %	74 51	73 19	53 08	77 00	71 50	42 50	37 50	64 56	77 46	2 28
protein (g)	25 51	23 62	11 04	16 87	21 00	38 50	54 00	4 35	1 71	6 56
fat (g)	0 82	2 97	13 25	4 95	6 17	15 00	5 19	8 56	0 10	36 40
ash (g)	1 48	1 46	1 46	1 05	0 80	2 40	3 17	1 66	0 72	3 95
carb (g)	nd	nd	21 18	nd	nd	3 00	0 45	20 69	20 01	50 81
calories (Cal)	116 00	128 00	249	112 00	143 00	294 50	264 00	178 00	86 00	542 00
cal from fat				44 50	57 00	135 00	46 50			
total fiber (g)	nd	nd	1 4	nd	nd	1 85	0 00	13 60	1 80	4 40
cholesterol (mg)	0 03	0 04	28	0 07	0 07	0 10	0 18	nd	0 00	0 00
FATS	sat (g)	0 23	0 79	2 76	1 56	1 81	3 44	1 54	2 03	4 01
	mono u (g)	0 16	0 78	4 2	2 10	2 42	4 95	1 74	1 39	15 99
	poly u (g)	0 34	1 11	5 70	1 28	2 02	6 55	1 85	5 15	15 98
	trans (g)	DL unknown	DL unknown	0 85	0 05	0 07	0 08	0 07	nd	0 05
vitamin a (IU)	57 00	20 00	85	135 30	48 71	46 75	136 50	2 61	3 00	nd
vitamin c (mg)	nd	nd	nd	nd	nd	nd	nd	nd	7 40	18 60
sodium (mg)	338 00	377 00	421	0 04	0 03	0 09	0 20	24 06	5 00	525 00
potassium(mg)	237 00	237 00	216	0 30	0 30	0 73	1 13	352 80	328 00	1642 00
calcium (mg)	11 00	14 00	26	0 02	0 02	0 34	0 29	287 00	8 00	24 00
iron (mg)	1 53	0 97	1 01	0 00	0 00	0 00	0 00	4 46	0 31	1 61
sucrose (g)	nd	nd	0 59	nd	nd	nd	nd	3 80	0 19	0 37
fructose (g)	nd	nd	0 27	nd	nd	nd	nd	0 60	0 30	
lactose (g)	nd	nd	0 00	nd	nd	nd	nd	nd	0 00	
maltose (g)	nd	nd	1 23	nd	nd	nd	nd	2 70	0 00	
Total PCBs <sup>c</sup> ng/g	nd			0 25ng/g	-	-	-	-	nd	-
p,p'-DDE <sup>c</sup> ng/g	0 21		0 06	2					0 02	
Total Hg <sup>b</sup> µg/g mean	0 12 µg/g <sup>2</sup>	0 41 µg/g <sup>2</sup>		0 11 µg/g	-	-	-	nd	-	-

<sup>a</sup>Nutrition data from USDA National Nutrient Database for Standard Reference or <sup>b</sup>Midwest Laboratories, Omaha NE.

<sup>c</sup>PCB and DDE data from (98), Mercury data from (99), or provided by <sup>b</sup>Midwest Laboratories, Omaha, NE.

My understanding is that Northway residents would like to trust the general assumption of wild food safety but, given the history of toxic waste, a survey of possible exceptions was appropriate. The most serious shortcoming of the Northway Wild Food Study is the limited number of samples analyzed, especially for persistent organic analytes in fish. No baseline averages or ranges were established, except for lead in roadside roots. Those roadside roots and two out of five snowshoe hares represent the clearest contemporary evidence of exposure, as well as the only documented exception to the sweeping general assumption above: most foods do not come with a detectable trace of lead. Other levels data we documented are comparable to those regarding the US food supply, which generally contains very low levels of the same and other synthetic chemicals (73, 100) and less nutritional benefit, as discussed in more detail below. More samples, especially of fish, should be analyzed for a credible evaluation of food safety.

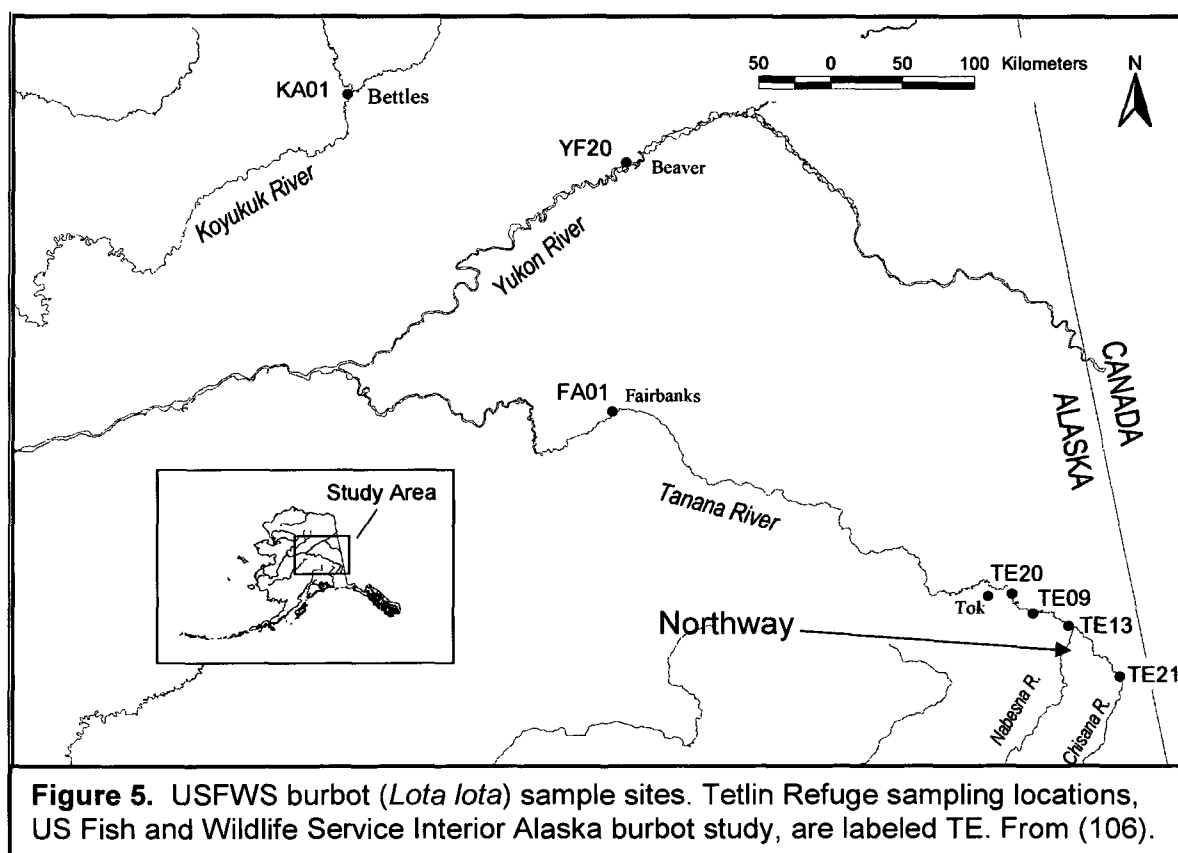
***Whitefish (Luugn; Coregonus pidschian)***

Mercury (Hg) was detected in both fish tested (0.06 and 0.15 µg/g) for metals while PCBs were found in the one tested (0.246 ng/g; average of duplicates). These samples were collected about 6 km downstream from the airstrip, at the confluence of Moose Creek with Fish Creek (Figure 2). While there is no indication of mercury in remediation documents, mercury is known as an atmospherically transported pollutant that accumulates in fish, even in very remote regions (101). The levels of Hg found in these two fish are comparable to or lower than humpback whitefish and many other species from other locations around the state of Alaska (102, 103) as well as commercially available whitefish (104), implying global sources. The levels are below Alaska's level of concern of 0.4 µg/g (51, 85) and lower than levels found in large long-lived marine species such as albacore tuna (*Thunnus alalunga*) that have raised national concern.

In 1987, the US Fish and Wildlife Service (USFWS) sampled livers from two Northern Pike (*Esox lucius*) and one Long Nose Sucker (*Catostomus catostomus*, rarely used for food). DDT was detected in one pike liver (0.01 µg/g, detection limit not given), along with 0.01 µg/g each of Endrin and Dieldren. The DDT metabolite dichlorodiphenyl-dichloroethylene (DDE) was found in both (0.08 and 0.71 µg/g). Only β-benzene hexachloride (β-BHC, also known as hexachlorobenzene (HCB) was detected in the

sucker, while many organochlorines, including PCBs, were not detected in any of the three fish; detection limits were not provided (48). A follow up study in 1990 analyzed 20 pike samples, muscle and liver, as well as multiple soil and sediment samples, and reported DDT and DDE in one fish liver (0.09  $\mu\text{g/g}$  Total) and one soil (0.18  $\mu\text{g/g}$ ) sample, detection limit 0.01  $\mu\text{g/g}$  (105).

In 1998, the USFWS conducted a study of organochlorines (OCs) in burbot (*Lota lota*) livers in five of Alaska's national wildlife refuges, including the Tetlin National Wildlife Refuge that surrounds Northway (106). Eleven samples were taken from four locations within the boundary of the refuge nearest the road (Figure 5).



Two PCB Aroclors (commercial mixtures of PCB congeners) were not detected in any Tetlin burbot liver samples, while two others (Aroclor 1254 and 1260) ranged from <0.0062 to 0.036 and <0.0058 to 0.15  $\mu\text{g/g}$ . Total PCBs had a higher detection limit (0.016  $\mu\text{g/g}$ ) than the Aroclor mixtures, which was exceeded in four samples, ranging

from 0.017 to 0.170  $\mu\text{g/g}$  (ww). Levels of other OCs (especially pesticides) were higher in different fish. Two burbot livers that were harvested upriver and close to the highway had the highest levels of a variety of OCs such as dieldren (0.0012  $\mu\text{g/g}$ ), hexachlorobenzene (0.0071  $\mu\text{g/g}$ ) and p'p'DDE. Only p'p'DDE was detected in every sample, ranging from 0.0014 to 0.028  $\mu\text{g/g}$  with a mean of 0.011  $\mu\text{g/g}$  (106).

These surveys show that OCs are present in Northway fish at low levels and the variability implies that the primary sources of contamination were local. This implication is supported by other research including a study in southern Yukon Territory that found local sources to be of greater significance than global sources of long range atmospheric transport from industrial regions (18, 107). Glacial runoff was a distant second as a source of OC contaminants to Yukon Lakes along the ALCAN (18). The actual contributions of local versus global sources remains unclear, but the Subarctic interior is expected to be less vulnerable to global pollutants than the Arctic environment, as it is offset from the global marine food web (88). Some fish are still taken from Moose Creek, but the runs are reportedly weak compared to decades past and most people go upriver to fish (71). The decision to fish upriver (southern tributaries, away from the road) adds expense that likely provides some protection from some contaminants, but how much protection, and from which, is unknown.

Meanwhile, this study tentatively supports the idea that whitefish are currently comparable in terms of contaminants and provide more substantial benefits than many store bought fish products, but there may be important exceptions. For example, mercury levels in light canned tuna are comparable to those in whitefish, and are higher in white tuna (albacore are larger and live longer than skipjack tuna (99)) while, in a different study, persistent organic pollutants are lower in canned tuna fish from US supermarkets (98), than in Northway burbot livers (106). For example, DDE was found in the USFWS burbot liver samples at about fifty times the levels in canned tuna (108), but still below regulatory guidelines of concern. In a study of contaminants in Subarctic lakes in Yukon Territory, the biomagnification factor of total DDT from whitefish to burbot liver appears to range from 4 to 40 (109). We can infer that DDE is lower in Northway whitefish than burbot livers, but no estimation is possible. No samples of whitefish from locations distant from the road system have been analyzed. Given their potential for

biological activity at very low levels (110), research of DDT and DDE and other persistent OCs in whitefish and pike from important fisheries is warranted.

***Muskrat (Dzanh; Ondatra zibethicus)***

Four muskrat samples were tested for metals. Lead (Pb) was found in both samples taken from a lake near the airstrip (30 µg/g and 0.11 µg/g) and was not detected in the 2 samples harvested upriver. Mercury (Hg) was not detected in the muskrat flesh samples (detection limit 0.02 ng/g), but was detected in a fur sample at 0.05 ng/g. Mercury concentration is expected to be higher in fur than flesh, because the level reflects years of cumulative exposure (81). The muskrat with the highest Pb was tested for PCBs, which were found at 1.21 ng/g. Muskrat from the airport lakes may have been a significant pathway of PCBs for individuals and families who consumed them in the 1950s and 60s, as briefly discussed at the June 26, 1995 public meeting in Northway (46).

***Roots (Tsüü; Hedysarum alpinum, H. hedysaroides)***

One of the benefits of the new road in the 1940s and '50s was the easy access it provided to prolific, edible roots that grew along the road and around the edges of the airfield (71). People ate roadside roots (Bear Root, or "Indian Potato") regularly for decades. Roots grow well in coarse and compact sand and gravel, and were formerly available only from river banks. Accessibility enabled women and children to dig roots along the road for hours at a time, many days a year. "Root picking" declined in the 1980s and 1990s with the general trend away from wild foods, but is still done.

Lead accumulated in roadside soil via automobile exhaust until lead was phased out of use as a fuel additive in the 1980s (111). Lead was found in 11 of 12 roadside root samples at an average of 0.285 µg/g. The twelfth sample was much higher than the others, at 26 µg/g. The higher sample comprised stunted plants growing around buried debris that seemed to be the remains of an old battery. Lead has several pathways of exposure including ammunition, chipped leaded paint, tobacco smoke, and even "lead free" plumbing that may contain up to 8% lead (112, 113).

***Snowshoe Hare (Gah; Lepus americanus)***

Easy rabbit hunting was another well appreciated advantage of roads. Snowshoe hares are commonly seen browsing along roads and are known to eat the stems and buds of Indian Potato plants (28). Rabbits are still hunted along roads in the summer, though not as commonly as in the past. Some residents also set snares in the winter, generally not far from the road. Lead was detected in two out of five snowshoe hares taken along local roads (5.9 and 11.4 ug/g), up to 40 times higher than in the roots.

***Moose (Diniign; Alces alces)***

Moose are currently the main source of wild protein in Northway. It is widely assumed that their vast and relatively pristine ranges keep them relatively free of contaminants, but very little evidence exists to support this assumption. Some residents are concerned about moose and the only moose samples analyzed in the Tanana watershed do show detectable levels of multiple contaminants including metals and persistent organic pollutants. The Tanana Chiefs Conference (TCC) conducted a Traditional Foods Contaminant Assessment of organic contaminants and heavy metals in a cow and fetus moose sample taken near Healy Lake, about 160 km northwest of Northway along the Alaska Highway. Healy Lake is along the Gerstle River, which drains the north side of the Alaska Range near Ft Greeley, and near an area used as a chemical and biological weapons testing ground in the 1950s and 1960s (9).

The TCC study documented the presence of Cd, Pb, PCBs, dioxins and furans, PAHS, and hexachlorobenzene in the Healy Lake moose tissue samples (114). Total PCBs ranged from non-detect in moose hair, to 0.067 ng/g in hindleg muscle. The only organochlorine pesticide detected was hexachlorobenzene. The metabolism of polycyclic aromatic hydrocarbons was noted as apparently slower than in fish, as detectable levels of most PAHs were noted. For example, naphthalene was detected at 116 ng/g in moose hair, 15 ng/g in the “book,” or third stomach, and at 7.89 ng/g (unconfirmed) in the hindleg muscle sample. Atmospheric deposition and uptake of contaminants to the food web via plants are known to occur (115), which suggests a need for a survey of contaminants in moose hunted along roads to elucidate spatial and temporal trends.

### ***Non-Foods***

#### *Wood Frogs (Naaxay; Rana sylvatica, also called Lithobates sylvatica)*

Although wood frogs were not collected or tested in this study, and are not a local food, residents reported seeing deformed frogs along Northway Road. “Maybe one or two in ten,” according to one family who lives very near old waste sites (116). Their observation matches the highest observed occurrence (14%) for a single breeding site in the Tetlin refuge that surrounds Northway in a 2007 USFWS study of wood frog abnormalities (117). The study, in five of Interior Alaska’s wildlife refuges, found that proximity to roads was strongly related to the occurrence of abnormalities. The Tetlin refuge ranked second highest in deformity frequency (5.9%), and was included with Kenai Wildlife Refuge (7.9%) as “...among the highest reported in the published literature (117).” The report suggests possible scenarios for why deformities might be more prevalent along the road, including chemical exposure. The results of the USFWS study were not known to the people the author spoke with about frogs, but local observations have long contributed to concerns about contamination. Those continued observations and the USFWS study speak to the need for local food web research.

#### *Moose Creek Water (Dzijlay Niign)*

The membrane of a Semi Permeable Membrane Device (SPMD) is intended to model bioaccumulation and results represent the total exposure over time in the water. The findings from Moose Creek are low, indicating that petroleum related polycyclic aromatic hydrocarbons (PAHs) have attenuated to levels that no longer present a hazard to human health. Even swimming in Moose Creek is unlikely to result in significant exposure. No testing was conducted upstream from the airstrip so a comparison to actual background levels is not possible. Given the passage of 65 years since the end of ALSIB operations, and extensive remediation in the 1990s, the data make no implications about historic levels of petroleum in Moose Creek. Water has long been a safety concern in Northway and multiple water sources there have raised suspicion over the years. A full study was beyond the scope of this project.

It should be noted that the military site had not been recognized as a threat to the Northway Washeteria well, which supplies the pump and haul water system on which more than half of Northway households depend until 2011. The Washeteria well is in the



village, directly down gradient from the western portion of the airfield (Figure 2). In a prior Source Water Assessment (118), the direction of water flow was misinterpreted and the protection area was drawn down river. The direction of water flow is corrected in the recently revised assessment. However, the drinking water protection areas are being shortened in a revision process across the state (119). In this case, the shortened protection zone means that the existence of the former defense site is left out of the calculation of vulnerability (120).

## **Conclusion**

The Upper Tanana River region of the Yukon River Watershed is a complex and largely intact ecosystem that contains variable but generally low levels of contamination. While no guarantee of food safety can be made, and the system is vulnerable to local and global forces of change, the limited data imply that wild foods are generally safe, especially when collected away from the road. Given the unknown effects of very low dose chronic exposures to synthetic additives and other contaminants in commercially produced meats and fish (74, 121, 122), and the documented risks of processed foods, the study tentatively supports the notion that wild foods are a healthier choice than processed foods that have become common across Alaska.

Most of the resources identified as pathways of exposure are historic. However, whitefish are still an important source of protein as well as cultural identity. Exposure to persistent organic pollutants remains unclear and more research is required for statistical comparisons and the determination of “background” vs. “elevated” levels, not to mention questions of biological availability and combined effects. An expanded study (increased samples and location) of whitefish and pike, tested for a suite of analytes is locally desired and would appropriately inform decision making in Northway.

Measurements today tell us very little about levels in wild foods decades ago. It is safe to assume that levels were lower prior to WWII and higher in the earlier decades since then, but the variation cannot be quantified. Implications about historic contaminant exposures are speculative, but justifiable. PAHs were logically the primary exposure, beginning immediately, but especially as the airfield was paved in 1944. Exposures to PAHs were probably highest in the 1940s, particularly for families along Moose Creek. PCBs and other industrial organics would have taken longer to work

through the food web, but are very persistent and may have been at their highest levels in the 1950s or 1960s, especially in Moose Creek fish. Pesticide and herbicide exposures likely began by inhalation, when roadside and pipeline spraying was active, and shifted to food web exposure over the years. Pb exposures were probably highest in the 1960s, when levels had time to accumulate and roadside roots were most commonly consumed. Root picking is much less frequent now, and Pb levels are presumably lower, but lead attenuates from roadsides very slowly (123).

Most local informants, only a few of whom were present prior to the war, reported that wild food use really declined in the 1970s rather than the 1940s (Appendix A). This was attributed mostly to increasing pressure toward and access to wage employment and grocery stores. Concern about contaminants was another important factor. Many residents continue to collect resources, but perceptions of contaminants have contributed to changing patterns and a general decline in use. This seems to be especially true among younger harvesters, who expressed confusion over the issue. The perceived protective benefit versus cultural loss of such adaptation is an unquantifiable reality for the people who live in Northway and struggle with decisions about what to eat. The data are limited and the assurance of safety provided by this study is qualified by uncertainty, particularly regarding spatial variation in levels of persistent organic contaminants such as DDE in whitefish and their interactions with each other and with mercury. While the indication of relative safety is helpful, more knowledge related to the state of wild food status today is needed for a full evaluation, especially of persistent organochlorines in whitefish.

## **2. THE NORTHWAY HEALTH STUDY: HEALTH CONDITIONS ASSOCIATED WITH HISTORIC RESOURCE USES**

### **Introduction**

There is little information available regarding the effects of chronic low level exposures to military and industrial chemicals in Alaska's remote rural villages despite the long history of toxic waste and concerns about food safety (1, 3, 4, 11). While the Northway Wild Food Study (NWFS, a limited survey of current contaminant levels in select traditional foods, Chapter 1) is important, if not entirely adequate, to address ongoing concerns about food safety, the data cannot be used to quantify or even reliably estimate historic exposures. The aim of this chapter is to describe the methods and design we used to evaluate associations between historical use of food and water resources and health problems in Northway, and the results of the comparisons we made.

The World War II military presence in Northway began a dramatic transformation of community health that eventually included a decrease in infectious diseases and an increase in non-infectious disorders, and which has caused concern about many factors that influence health, especially toxic waste. The objective of the Northway Health Study was to answer the general question "Why is there so much sickness?" that was raised during initial interviews. Numerous suspicions voiced in those interviews provided endpoints for a health study to investigate possible associations between suspected historic resources and health problems.

The Health Study Team (several Northway residents and me) decided to approach the question by comparing the incidence of generalized health problems among users of certain resources to non-users in a retrospective cohort study. Data, based on memories and subjective knowledge, were collected regarding food and water resources used, as well as the demographics and health of household members. Information was collected for current as well as historic Northway households, providing data for a total of 325 individuals. Independent binary comparisons of the odds for seven general health problems were made for users versus non-users of each resource. Several important aspects of health, e.g., lifestyle and genetic risk factors, were not controlled for in the study.

Multiple complex associations were found, some of which were stronger in historic households as compared to existing households, and some of which became stronger with the combination of data; none were strongest in existing households. In general, reported users of Moose Creek as a water source (1940s-1980s) reported a higher incidence of cancer ( $OR = (24/116)/(11/140)$ ,  $p = 0.0047$ ), fish consumers reported a higher risk of thyroid problems ( $OR = (13/240)/(0/75)$ ,  $p = 0.027$ ), and reported users of FAA water and the Haines-Fairbanks Pipeline corridor reported a higher incidence of several other health problems. Despite epidemiological limitations, these associations imply that known historic sources of pollution contributed to human health problems via food and water exposure pathways that were inevitably more significant in the past.

### **Design and Methods**

The myriad interactive environmental and social factors that have influenced public and cultural health in Northway to this point are not well documented, but many, especially changing dietary patterns, are well remembered by community members. In such situations, anthropologists often use collective local knowledge to identify patterns and trends (124, 125) and that was the approach taken here. The Northway Wild Food and Health Project was approved by the University of Alaska Fairbanks Institutional Review Board in 2005 (05-31 and 09-06; Appendix D). Design, implementation, and reporting of the project was guided by formal and informal local input.

Health concerns raised by Northway residents were generally vague, but reminiscent of the toxicological literature. Cancer was the primary concern, named by all informants during the initial interviews in 2005 and 2006. Other illnesses, especially thyroid problems, learning disabilities, autoimmune disease, and reproductive problems were also identified as possibly related by several participants. Many people had mentioned concern over metabolic disorders such as diabetes and heart disease, but with less concern about a connection. The most common suspicion, by far, related Moose Creek water with cancer, while whitefish and the Haines Fairbanks Pipeline were also suspected of having made people sick. Additional concerns were raised about eating edible roots and berries gathered along the road, and muskrat—which are more

delicious than they sound. Water from the tank at the FAA facility was second only to Moose Creek as a water source of concern.

The study would attempt to evaluate and possibly clarify the general suspicion that local wild food and water resources had contributed to illness. It was emphasized that the study would not provide proof, and might not even have the statistical power needed to “find” relationships of association between resource uses and illness.

An informal Steering Committee (listed in acknowledgements) recommended attention to cancer, thyroid and reproductive problems, and diabetes as the health study was planned. Because a health study would need substantial community guidance and support, the Health Study Team was formed to help design and conduct the research. The retrospective cohort study would compare the incidence of certain general health problems between groups of people based on whether they had consumed particular resources. There would be three data sets for the single population across time: *Existing Households* to include people living in Northway (2009); *Historic Households* to include those who had moved or passed away; and *Combined Households*, a third, pooled dataset (duplicates removed), for more robust statistics.

### ***Data collection***

#### ***Existing Households***

In the spring of 2009, a questionnaire was sent to all 90 existing households in the Northway area to collect information about household demographics as well as the historic food and water resources used (Table 6) and health conditions (Table 7) of household members. “Household” was loosely defined as a group of people who live together. Raffle prizes were offered for returning the questionnaire by an early deadline. Members of the Health Study Team solicited participation and assisted some households with completing the questionnaire, and data collection went on through most of the summer. Team members documenting other people’s personal knowledge completed an online training course from the University of Alaska Fairbanks Institutional Review Board. Follow-up phone calls to respondents focused on 1) clarification of (historic) food and water sources, especially historic caribou use, 2) use of the Haines-Fairbanks Pipeline corridor for collecting resources, and 3) the possibility of doing a “historic household interview.”

<b>Table 6. Resources included in the Northway Health Study.</b>	
<b>Resource</b>	<b>Time of use</b>
Moose Creek water	pre-war – 1980s
Whitefish <sup>a</sup>	pre-war – present
FAA water <sup>b</sup>	1950s – 1980s
Beef	1970s-present
Caribou <sup>c</sup>	1950s – 1970s
Edible Roots from along the road <sup>d</sup>	1940s – present
Haines-Fairbanks Pipeline corridor (multiple resources)	1970s – 2000s
<sup>a</sup> Broad and Humpback Whitefish ( <i>Coregonus nasus</i> , and <i>C. oidschian</i> ) <sup>b</sup> The Federal Aviation Administration had a public-use well and tank at their airport facility. <sup>c</sup> Caribou ( <i>Rangifer tarandus</i> ) consumption in the era of above ground nuclear weapons test was a possible concern. <sup>d</sup> Roots, or “Indian Potato” ( <i>Hydysarum alpinum</i> and <i>H. hedysaroides</i> ).	

<b>Table 7. General Health Conditions Included in the Northway Health Study.</b>
<b>Cancer</b> includes any type or site of cancer; several pre-cancers not included; <b>Thyroid Problems</b> include hypo, hyper, enlarged, and undefined thyroid problems; <b>Reproductive Problems</b> birth defects and failed pregnancies counted toward mother; <b>Cardiac Irregularities</b> include murmurs, arrhythmias, and undefined irreg. heartbeat; <b>Blood Glucose</b> includes pre, gestational, diabetes types I and II, and hyperglycemia; <b>High Blood Pressure</b> includes medicated and managed cases; <b>High Cholesterol</b> includes medicated and managed cases.

### *Historic Households*

Interviews were conducted with individuals who had knowledge of a household that no longer existed, provided they could describe the food and water resources used, as well as the demographics and health of the individuals who lived there. The informants were usually older adults who described their childhood household and sometimes their own early household. In all but one case, the informant had been a member of the former household; in that case, the informant described her

grandparent's household. Uncertain information was not included if it could not be verified by another family member, but confident statements were taken as data. Since three additional conditions had been reported at least a few times in existing households (cardiac irregularities, high (low density lipoprotein (LDL)) cholesterol, high blood pressure), those conditions were also queried during the historic interviews.

### ***Data Treatment***

Household residents were assumed to have used the same resources as the head(s) of household during the time they lived there, unless other information was provided. If information on a resource was not recorded for an individual, or they were not in Northway at the time, they (and their family) were not included in the comparison. Resource uses were simplified to a binary yes or no response. Sources of protein were ranked as "yes" for consumption if they were named as one of the top three consumed and "no" if they were not named in the top three (whitefish and salmon were listed with other common meats on the form). There were two exceptions made to this rule. In those cases, whitefish was named as the fourth protein source. The families' history of regular consumption of whitefish was verified, although fish may have been a more seasonal resource than for other families. Both of these families reported thyroid problems that were included in the study. Caribou (1950s-70s) was one of three resources (with the Haines Fairbanks Pipeline corridor and edible roots collected along the road or airstrip) that were asked about specifically. Current caribou consumers were ranked as a no response if caribou was not consumed until the 1990s, when a migration shift made them much more accessible. Rare use of these three resources (<1 / year) was ranked as a no response.

Occurrences of illness were not scaled by severity or temporality, and were simplified to a binary yes or no response, as described in Table 7. None of the documented health conditions were confirmed with medical records. Although it might have been helpful in evaluating the strength of associations, there was no formal statistical analysis of cross correlation between multiple resource uses or disease occurrence, in part because each of the associated resources has the potential to be a genuine risk factor. The issue of common resource uses among people reporting health problems is further discussed below and in Chapter 4.

Fifty individuals who were included in both original datasets were kept for those analyses, but were removed from the current households data before the two datasets were combined to avoid duplication. Nine individuals in responding current households were not included in comparisons because they had either arrived in Northway within the previous two years or had alcohol related developmental disorders. For each of the three final datasets, the data were analyzed with SAS statistical software in one program for each resource that included code for an independent binary comparison of users versus non users for each general health problem with a two tailed Fisher's Exact test using SAS statistical software (126).

### **Limitations**

These data represent personal events that occurred as long as 70 years ago and include second-hand, subjective information. Though not always verifiable, anthropology has long recognized patterns described by human testimony as valid (127) and the study proceeded with the assumption that people reliably know the general food sources and health conditions of people they live(d) with. However, even assuming that these household accounts provided accurate data, other limitations exist.

To allow for such a broad study in a small population, scales of resource use and severity of illness were simplified to a yes or no response, with "rare" resource use ranked as a no response. The subjective line between "rarely" and "sometimes," although defined, was the greatest potential source of systemic measurement error. The simplicity of yes or no comparisons, while allowing for a broad review of patterns, limited the analysis to very basic questions of association.

Each binary comparison of the odds for illness between users and non-users of a resource was independent. Cross-correlation of resource uses present an important, and interesting, confounder that is discussed in more detail in Chapter 5. Given likely bias (higher returns from families with disease) the study cannot claim to represent Northway as a whole, and extrapolation of the disease incidence for Northway's population cannot be made from any of the datasets. Thus, the term "risk," when is applied to study participants, is relative only to compared study participants. Most importantly, other established personal risk factors for cancer and other health problems, such as tobacco and alcohol use, the consumption of mass produced and processed foods, and genetic



risk factors (128) and vulnerabilities to the effects of toxic pollution (128, 129) were left uncontrolled and unexplored.

These and additional sources of uncertainty are discussed throughout this dissertation, especially in Chapter 5. Strictly speaking, this study is epidemiologically limited and more accurately defined as an exploratory survey. Physiological health effects are but one piece in a complex set of repercussions resulting from military construction and activity around Northway. This study does not pretend to be comprehensive, even for this one piece. Further, the military has never been the only force of change, and military waste has never been the only source of toxic chemicals.

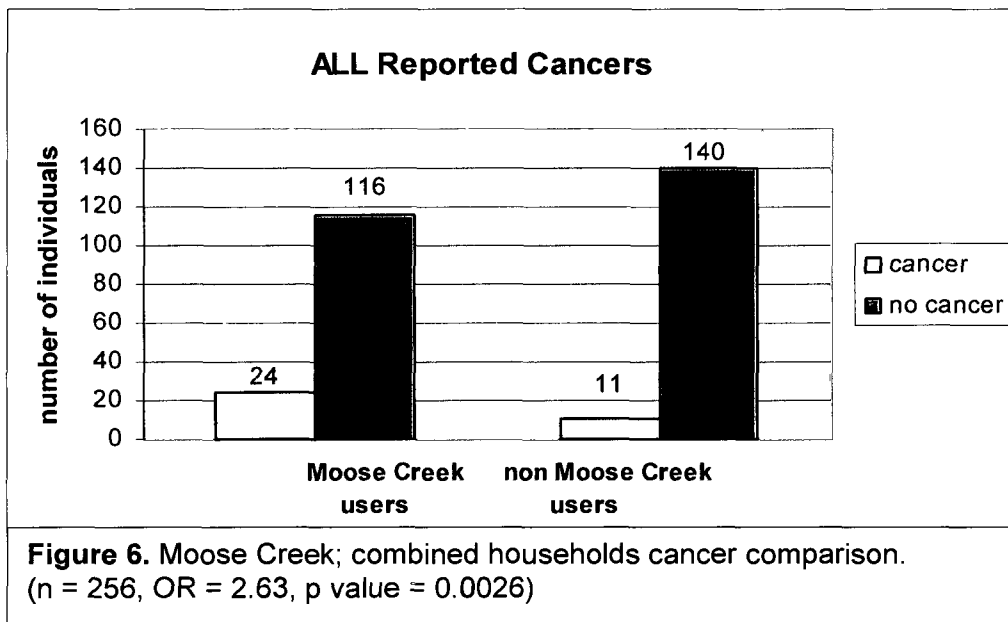
## **Results**

Fifty-nine out of 90 existing household questionnaires were returned over three months, providing information on 178 of an estimated 360 current residents (14, 15). Historic interviews collected data about 197 individuals from 24 households that existed between 1940 and 2005. The actual number of households that existed during that time period is unknown. The apparent decrease in household-size is real but likely exaggerated by a relatively low return of questionnaires from younger households that have more children. The combined dataset totaled 325 people. Details such as age-at- or year-of diagnosis were not usually given, thereby decreasing the analytical power of the study.

As simply stated in the introduction, certain historical resource uses are implicated as significant risk factors for particular health problems: results that can be reasonably explained by known but poorly-recorded historic sources of contamination. Whether multi-factorial statistical analysis could have overcome the small numbers of cases, the uneven distribution of people in some comparisons, and other confounders for a meaningful model remains unknown. Regardless, without hard evidence such as quantified historic exposure routes, toxicological biomarkers, and knowledge of biochemical mechanisms, definitive conclusions are impossible to draw. Nonetheless, those sources of contamination are the most reasonable explanation of the patterns, despite the lack of causal link. The findings are briefly described here and discussed in more detail in Chapters 3, 4, and 5.

### ***Moose Creek and Cancer***

As expected by many informants, the use of Moose Creek (1940 ~ 1980) as a water source was very strongly associated with cancer risk (Figure 6;  $n = 116/256$ , Odds Ratio (OR) = 2.63,  $p = 0.0026$ ). The users of three other resources also reported a higher incidence of cancer in the combined data, with decreasing statistical certainty: Whitefish ( $n = 240/315$ , OR = 2.42,  $p = 0.047$ ), FAA water ( $n = 126/253$ , OR = 1.92,  $p = 0.54$ ), and roots ( $n = 174/299$ , OR = 1.98,  $p = 0.055$ ). The difficulty of distinguishing between cross-correlation and real contributions is discussed in more detail in Chapter 5. Reported cancers are listed in Table 8.



### ***Whitefish and Thyroid Problems***

Fish consumers showed a consistently increased risk for thyroid problems and the comparison was most significant in the combined dataset when comparing people who had never eaten (Northway) fish as a major source of protein to people who had (at some point since the 1940s). Eating whitefish was significantly associated with thyroid problems in the existing and combined datasets (Table 9). Historic cohorts were too uneven (11 cases among 176 fish eaters compared to zero cases among 20 people who did not eat much fish) for good comparisons in the historic households dataset. Fish consumption was also associated with cancer in the combined data (above). Reported thyroid problems are listed as they were described in Table 10.

<b>Table 8. All reported cancers.</b>			
<b>Sex</b>	<b>Year of birth</b>	<b>Cancer</b>	<b>Other</b>
6F 3M	1909-1928	leukemia	
		prostrate	
		breast	repro
		ovarian	
		breast	thyroid
		multiple myloma	repro
		colon	
		lung	
		intestinal	
12F 6M	1934-1949	lung (not a smoker)	
		colon	
		skin	
		leukemia	
		leukemia	
		prostate	
		lung	
		skin and prostate	
		breast	
		lung	
		lung	
		multiple myeloma	repro
		breast	
		breast	repro
		lung	
		breast	thyroid, repro
		breast	repro, card irreg
		breast and intestinal	
		breast	diabetes, repro
7F	1950-1969	liver	
		breast	
		breast	
		breast	repro
		stomach	
		uterine	
		breast	

<b>Table 9.</b> Whitefish and thyroid problems. Odds Ratio = incidence among reported fish consumers / people reported to have not consumed fish regularly: and p value.								
<b>Historic data (n = 197)</b>			<b>Current data (n = 178)</b>			<b>Combined data (n = 325)</b>		
<b>Odds Ratio</b>		<b>p-value</b>	<b>Odds Ratio</b>		<b>p-value</b>	<b>Odds Ratio</b>		<b>p-value</b>
$\frac{11/175}{0/20}$	<i>i</i>	0.29	$\frac{7/108}{0/61}$	<i>i</i>	<b>0.041</b>	$\frac{13/240}{0/75}$	<i>i</i>	<b>0.027</b>

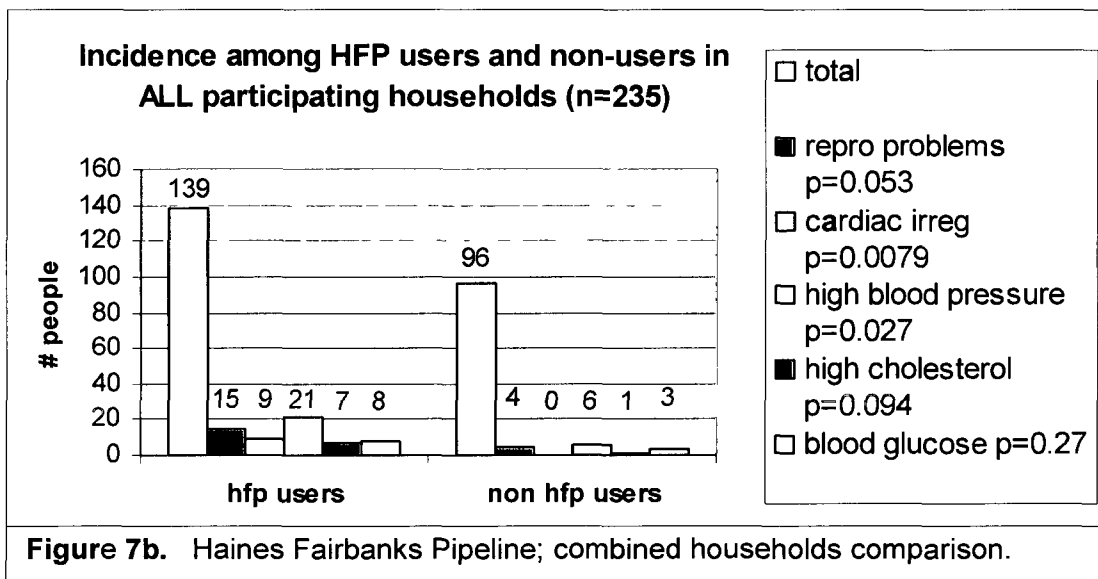
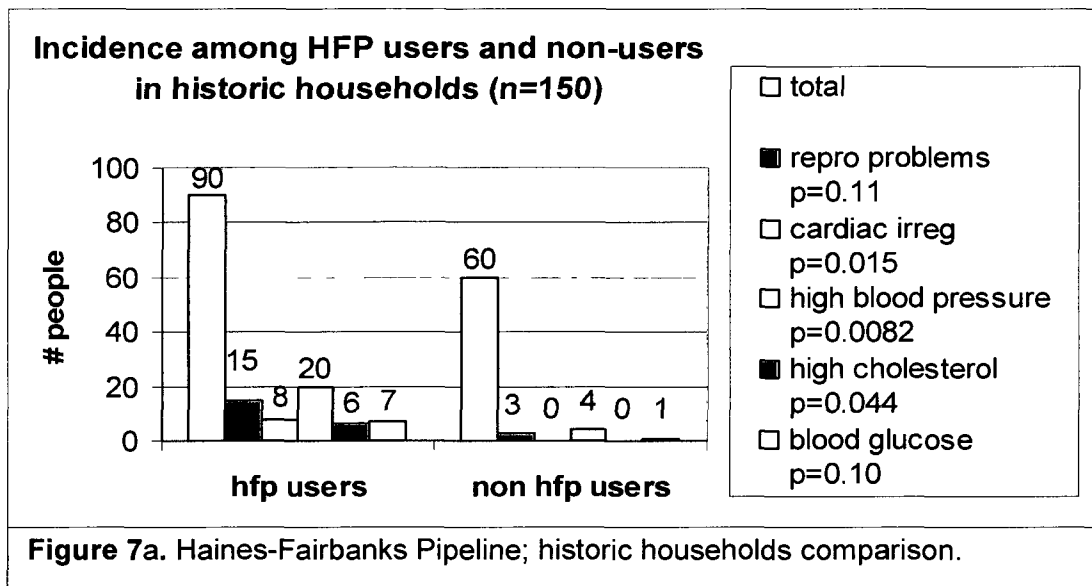
<b>Table 10.</b> All reported thyroid problems.			
<b>Year of birth</b>	<b>Notes on thyroid problem</b>	<b>Notes on other conditions</b>	<b>Other notes</b>
1906	undefined thyroid		pneumonia
1916	thyroid surgery	breast cancer	undefined heart problems
1940s	no thyroid		lupus (1980s), gr dtr has downs syndrome
	problems since 1980s	breast cancer, repro (irregular periods 2 premature births)	child with cerebral palsy, daughter and her son cancer
	"problems"		always skinny
	was hyper now hypo	high cho, high bp	
1950s and 1960s	enlarged (2000s)		always skinny
	hypothyroid;	repro (excessive bleeding)	allergies
	thyroid problems when young	blood glucose regulation cardiac irreg high blood pressure	allergies, ashma, dep/anx,
	enlarged		
1970s	surgery @14		
	undefined thyroid	high blood pressure	depression / anxiety born lbw, milk allergies
2000s	since birth		

One family also reported thyroid problems in two daughters (not included in the study) of a woman who was included in the study with no reported health problems of her own, and who had left Northway when less than one year old. While she may have experienced additional exposure to thyroid disruptors prior to the birth of her daughters, the literature demonstrates that effects from sub-clinical thyroid disruption through multiple generations of offspring are plausible (130, 131).

Eating whitefish in the 1990s and 2000s was also significantly associated with blood glucose problems (as defined in Table 7) in the historic and combined datasets data not shown). Many of the diabetics still eat fish, but 11 of 13 people with reported blood sugar regulation problems had consumed fish regularly; thus some genuine effect from earlier fish consumption cannot be ruled out. The association with blood pressure and cholesterol is generally negative: fish consumers reported a lower risk that was sometimes statistically marginal. These relationships are strongest in historic households ( $n = 176/196$ ; OR = 0.060,  $p = 0.0011$  for high cholesterol; OR = 0.40,  $p = 0.032$  for high blood pressure). Thyroid problems were associated with pipeline use in existing households, but that comparison includes only five out of 13 reported thyroid cases. Seven reported thyroid cases used the pipeline while all thyroid cases consumed whitefish.

### ***The Haines-Fairbanks Pipeline Corridor and Multiple Health Problems***

Among historic household members, reported users of the pipeline had an apparent higher risk of five generalized problem categories shown in Figure 7a, though the association was not always statistically significant. In existing households, the odds ratio, or “risk,” for each of these conditions is greater than 1.5 among reported users of the pipeline, with some 80% likelihood for these associations ( $p$  values  $\leq 0.20$ , data not shown). When the two datasets were combined, statistics for irregular heartbeat and reproductive problems were strengthened, while statistics for the metabolic problems (high blood pressure, high (LDL) cholesterol, and blood sugar regulation) were weakened (Figure. 7b).



Other resources were associated with these five health problems. In the combined dataset, FAA water users ( $n = 126/253$ ), had a higher risk of reproductive problems: (Odds Ratio = 4.0,  $p = 0.0042$ ), irregular heartbeat (OR = 3.5,  $p = 0.084$ ), and high (low density lipoprotein (LDL)) cholesterol (OR = 6.0,  $p = 0.060$ ). In historic households, people reporting store-bought beef consumption in the 1970s and '80s ( $n = 59/125$ ) showed a higher risk for high blood pressure (OR = 3.5,  $p = 0.0018$ ) and high cholesterol (OR = 5.6,  $p = 0.080$ ), while fish eaters ( $n = 176/196$ ) showed a lower risk for

those problems (OR = 0.38,  $p = 0.032$  and OR = 0.057,  $p = 0.0011$ , respectively). These theoretically predictable nutritional benefits (132) and risks (133) lend support to the legitimacy of the data. These trends were sustained in the combined dataset with less statistical significance (data not shown), which seems to indicate that other factors are increasingly important. Fish eaters also had a higher risk of blood glucose problems that was statistically significant only among fish eaters in the 1990s and 2000s, most strongly in the combined dataset, discussed further in Chapters 3 and 5.

## **Conclusion**

Together with historic documents regarding pollution and extensive toxicological literature, these associations suggest that effective but non-quantifiable levels of contaminants were present in historic resources as further discussed in Chapters 3, 4, and 5. In the absence of details regarding historic exposure across the population, the food and water resource data stand as a proxy indication of various unquantifiable historic exposures that were likely to have had effects, and show that locally informed research is a promising way to investigate the historical context. Very limited data on fish contaminants collected by the USFWS provide the only hard, and still indirect, evidence that human exposures occurred (105, 106). Nonetheless, the Northway Wild Food and Health Project documents the legitimacy of local concerns and perceptions, and provides information that answers some questions while raising many more. While additional research could be locally insightful and toxicologically relevant in many ways, enthusiasm may be limited without stronger possibilities of more definitive conclusion and compensatory response.

### **3. IMPLICATIONS OF PETROLEUM AND PERSISTENT ORGANIC POLLUTANT EXPOSURE DOWNSTREAM FROM THE NORTHWAY AIRFIELD**

#### **Introduction**

Historic exposures to petroleum products including leaded fuel and persistent organic pollutants around the Northway Staging Site are poorly documented and cannot be quantified. We infer, however, that polycyclic aromatic hydrocarbon (PAH) and pesticide exposure began in 1942 along Northway Road and Moose Creek via inhalation, ingestion, and direct contact. Pesticide and other persistent organic exposure is thought to have continued via food web exposures long after ambient source-levels had declined. Levels of persistent organics like PCBs (polychlorinated biphenyls) and DDT (dichlorodiphenyltrichloroethane) in fish may have been highest in the 1950s or 60s, considering the time needed for the processes of bioaccumulation and magnification, followed by attenuation and remediation. Muddy glacial water invaded the primary fishery on Fish Creek in the 1970s, which shifted some fishing to Moose Creek for a while (134), but consumption of fish from Moose Creek is rare now. The idea that whitefish were polluted and contributed to illness is painful for Northway people; the suggestion was made, but not forcefully asserted during interviews. Some families go upriver to fish, which costs more in fuel and time. Many families have stopped eating so much fish, or have increased their acquisition of salmon (135) from elsewhere (71).

The Northway population of 361 people is approximately 76% Athabascan and 20% mixed race (14, 15). The Northway Health Study included native, mixed-race, and white families. Race was not tracked in the study, but it can be said that consumption of fish was reported by all native and mixed-race families early on (1940s-60s), while about half reported using Moose Creek (pre-war until the 1970s or 1980s). No all-white families reported use of either of these resources, but some reported using the other studied resources such as caribou and the Haines Fairbanks Pipeline corridor (HFP). All thyroid problems were reported among fish eating (native or mixed race) families. Whites were included in the data for other health problems, especially in the heart disease categories, which may reflect a less favorable ratio of saturated to unsaturated fats.



### **Moose Creek and Cancer**

In 1942 or 1943, mostly-emptied oil barrels were reportedly filled with sand and piled in Moose Creek, which was then backfilled, allowing the construction of the 7500 foot (2.3 km) airfield (35). A gravesite and a fish camp were destroyed in the process (136). No debris was identified with metal detectors during the remedial investigation. The airstrip remains in place (13) and was repaired to nearly original length in 2009 and 2010. In 1944, an asphalt plant operated near the east end of the airfield, where Northway Road crosses Moose Creek, and the airstrip was paved (35). The abandoned plant was demolished sometime after the war, and adjacent open tar mounds sat for decades. The creek was also polluted with leaded-petroleum and pesticides at other waste sites (Figure 4).

Until the 1980s Moose Creek was the primary source of drinking water for many households along the road that roughly parallels the creek (Figure 2). While Moose Creek (Dzjijay Niign) was an important clear water source for families who had summered in Fish Camp and wintered in Moose Creek Village, a full third of the individuals reporting cancer in our data did not report consuming Moose Creek water. It is generally understood in Northway that cancer has many causes, including secondhand smoke as a child. However, it is clear that unknowable exposures to petroleum and pesticides occurred, especially for families who lived along the creek and used it as a primary water supply during and following the war effort.

Many petroleum related polycyclic aromatic hydrocarbons (PAHs) and heavy metals, as well as various pesticides, especially DDT and its metabolite DDE (dichlorodiphenyldichloroethylene), have been shown to initiate or promote cancer and other diseases by multiple mechanisms in animal studies (137-139). Likewise, clinical human studies have found that these chemicals are among the many contributing factors for cancer and other diseases (140-148). In Northway, the preponderance of cancers reported among those born in the late 1930s and 1940s (Table 8) seems to imply that at least some of the cancers were initiated by exposure during development and then manifested in adulthood (149, 150).

PAHs are more water soluble than the organochlorines (OCs), such as PCBs and DDT that would be more likely to reach people via fish consumption (81). This makes PAHs the most likely reason that Moose Creek water would be associated with

cancer, but multiple concurrent exposures must have occurred—and not just along Northway Road. Nonetheless, the well-remembered waste along Moose Creek is the most reasonable explanation of different cancer rates between users and non-users of Moose Creek, even with other factors, such as fish, FAA water, tobacco, and genetic susceptibility in contributing roles (151).

An unofficial record of diagnosed cancers kept by an anonymous local resident lists 43 individuals. Most of those people are said to have lived in households on Moose Creek as children. Of the 35 individuals with cancer in our study, 27 are included on that list. We are apparently missing some 16 additional cancers, at least 12 of which were reportedly in families from Northway who have moved or passed away. Of these individuals eight had lived on Moose Creek, including an adult male thyroid cancer diagnosis in the 1970s. We have documented nine cancers not on that list; the majority of these individuals were white men and women who had grown up elsewhere, some of whom lived in FAA housing at the airfield. As reflected in our data, breast cancer dominates the list. Several of the unreported cancers (on the list, but not in our study) are recorded as lung cancer, which suggests a response bias with an under-reporting of lung cancers in our data. However, most of the unreported cancers, including lung, were among the individuals who reportedly lived on Moose Creek as children. The list suggests that if the study had been limited to people born and raised in Northway, the statistics regarding Moose Creek would have been stronger. It seems generally understood in Northway that smokers on Moose Creek (and their families) had the highest risk.

### ***Other Associations with Cancer***

Three other resources were significantly or near-significantly associated with cancer in the combined dataset: whitefish, FAA water, and wild, edible roots from along the road ( $p = 0.047$ ,  $0.054$ , and  $0.055$ , respectively). While significant cross correlation of resource uses exists, all three of these resources were pathways of exposure to toxic chemicals that could have been contributing factors. A thorough analysis was not conducted but the association, for example, between Moose Creek and fish was stronger among cancer cases than among all participants (data not shown), supporting the likelihood of contributing resources.

Almost everyone born and raised in Northway ate fish, most of which came from Fish Creek until the 1970s, including nearly everyone who used Moose Creek. People living on Moose Creek probably ate some fish from Moose Creek, which may have been more polluted than those in Fish Creek. This unquantifiable variation makes the relationship between fish and cancer unclear, but fish were an inevitable pathway of various organic contaminants, as discussed below, and seem likely to have been a genuine contributing factor. FAA water was chlorinated and frequently mentioned as suspect. Edible roots from along the road were very popular for decades. Roots were found to contain low levels of lead in testing done for this project (0.12 – 26 µg/g; Chapter 1). Both chlorinated-byproducts of water treatment (152) and lead (153) have been associated with cancer elsewhere, so neither can be clearly identified or dismissed as a contributing risk factor for cancer among study participants.

### **Whitefish and Thyroid Problems**

In terms of ongoing nutritional, cultural, and economic considerations, whitefish are the most important resource evaluated in the study, and the safety of their consumption is an ongoing concern that was somewhat alleviated by the Northway Wild Food Study. Whitefish have always been an important source of protein and dietary oil in the far Upper Tanana River region, where salmon runs were never strong and no longer exist (154). Relationships of whitefish consumption to illness are difficult to discern, at least in part because many more participants ate fish than did not eat fish, making comparisons uncertain with or without the use of statistics. However, the strength of association between whitefish and thyroid problems is robust because all of the thyroid cases came from fish eating families (Table 9). All 13 individuals with reported thyroid problems were female, with years of birth that span nearly a century (1906-2002), though the majority of these women and girls were born in the 1940s-60s (Table 10).

DDT, the metabolite DDE, as well as PCBs and their metabolites, have been documented in Northway pike and burbot (Chapter 2 (47, 105, 106)). These contaminants are all known thyroid disruptors, especially during early development, in animals (155, 156) and people (157, 158). It is clear that fish from Moose Creek and, probably to a lesser extent, the Fish Creek tributary were exposed to PAHs, pesticides, and other pollutants during and after the war, and that they were most likely higher than

exposures to fish at remote sites. The biomagnification of persistent pollutants from fish to fish consumers is well documented (159), and evidenced in Northway (106).

PCBs were found at 0.247 ng/g (average of duplicates) in the one whitefish tested for this project, and ranged from non-detect to 170 ng/g in a 2000 study of burbot (*Lota lota*) liver contaminants in the Tetlin National Wildlife Refuge that surrounds Northway (106). The burbot liver with the highest levels of persistent pesticides, including DDT and DDE, was taken 20 miles upriver, along the highway. In contrast, the highest PCBs were found in a liver from several miles down river. None were taken from Moose Creek. The only contaminant detected in all burbot livers was p'p'- DDE (106). No other data for contaminants in whitefish exists, but high variability in the burbot data suggests that local sources dominate over global sources, as in Southern Yukon (18).

## **Conclusion**

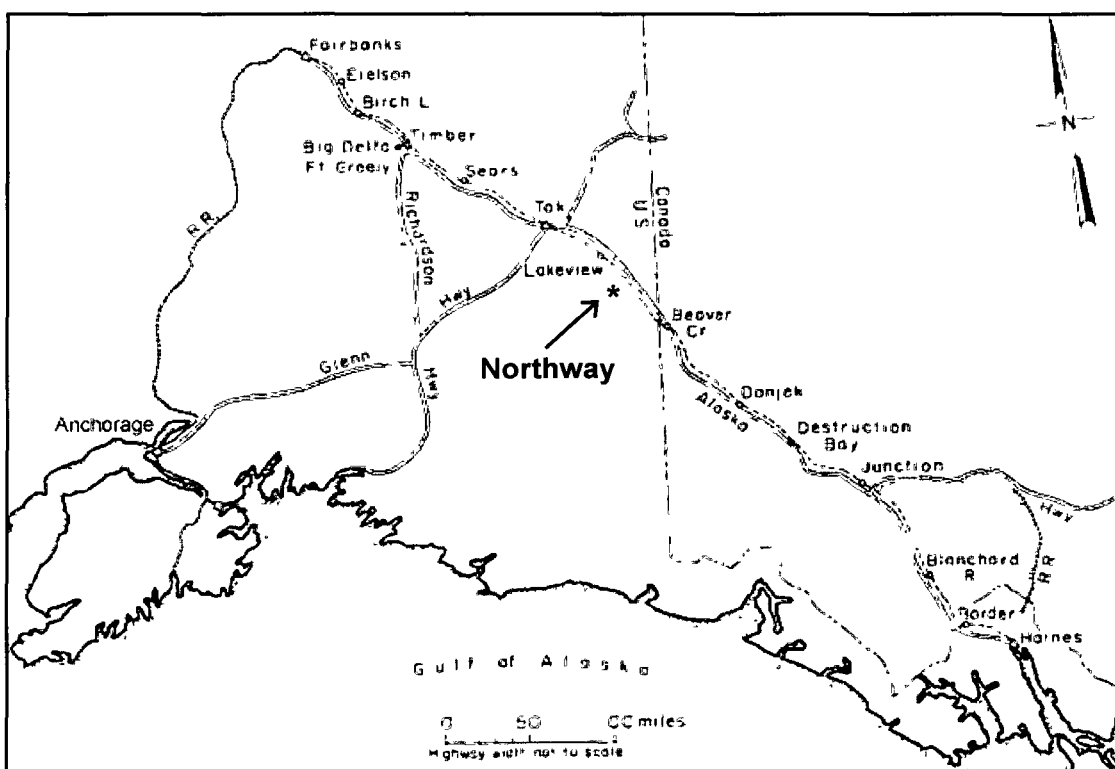
Although the general implication that pollution along Moose Creek contributed to cancer and thyroid problems is clear, this study illuminates several points of confusion. The fact that most people in Northway ate fish, including almost every one who used Moose Creek, confounds comparisons, and the relative contribution of Moose Creek water vs. fish consumption toward cancer cannot be quantified. Moose Creek users have a slightly higher risk of thyroid problems (not shown) and it seems clear that fish made a more significant contribution to those. However, the common use of both resources among individuals with cancer and the historic contamination of both resources by multiple pollutants, raises the possibility of cumulative effects of various contaminants (160, 161) and makes the situation extremely complex.

Given Northway's history of belated remediation and the trends revealed by the toxicological literature, the findings are entirely feasible. Participants are neither surprised by nor doubtful of the findings, and have welcomed a better understanding of the details despite remaining questions about actual exposure histories, interactions among contaminants, and the possibility of intergenerational effects. A screening of thyroid function, especially for young women and children is warranted (131), and a detailed study of whitefish contaminants, and methods of preparation to minimize exposures, is needed for a thorough evaluation of their current status.

#### 4. IMPLICATIONS OF DIOXIN EXPOSURE IN THE HAINES-FAIRBANKS PIPELINE CORRIDOR

##### Introduction

Military activity at Northway was centered at the airport. However, another important piece of the exposure-history puzzle in Northway is the Alaska Canada Gas and Oil Pipeline (ALCANGO) or Haines-Fairbanks Pipeline (HFP) that paralleled the highway down the Upper Tanana. The Haines-Fairbanks Pipeline (HFP) was active from 1955 to 1973 and transported petroleum from the seaport in Haines, Alaska through Canada to military bases near Fairbanks and points between (Figure 8).



**Figure 8.** The Haines Fairbanks Pipeline, 1955-1973. Northway location is approximate. The Lakeview Pump-Station was further south-east than shown, east of Northway. Currently, an Alaska Department of Transportation facility is located on the site, while a nearby US Fish and Wildlife Service Campground is called Lakeview. From (162).

The HFP corridor was used by local residents, especially in the 1970s and 80s and through the 1990s, primarily for raspberry picking. After berry picking in the corridor had declined due to overgrowth in the 1990s, news spread in 2002, that the herbicide Agent Orange had been used in the corridor (163, 164). The fact that herbicides were used to keep the pipeline visible for aerial inspection is not disputed, but which herbicides and how often they were applied was not well documented during the first 10 years of the pipeline's operation as described below.

Raspberries, years and decades later, would not be an important pathway for lipophilic contaminants since such compounds do not dissolve well in the water taken up by plant roots. However, as the study proceeded, it became clear to the lead author that the corridor had been popular for collecting many other resources including various berries, mushrooms, edible roots, basket roots, as well as firewood for smokehouses. Edible roots were sometimes brushed off and consumed, while basket roots were sometimes "split" on-site, by biting the end and tearing lengthwise. "We'd put them right in our mouths, just sitting there in the dirt (165)." Hunting and picking were so good that people camped in the corridor. As far as we know, the pipeline corridor is still used for traveling, trapping, and diamond-willow collection, but is no longer used for collecting edible resources.

In all three datasets (existing, historic, and combined), users of the Haines Fairbanks Pipeline corridor for collecting resources (1970s-90s) reported a higher incidence of the three metabolic disorders as well as reproductive problems and cardiac irregularities, with statistical strength ranging from marginal to strongly significant. The associations for the metabolism disorders were strongest in the historic households data (high blood pressure OR =  $(20/90)/(4/60)$ ,  $p = 0.0082$ ; high LDL cholesterol OR =  $(6/90)/(0/60)$ ,  $p = 0.044$ ; blood glucose problems OR =  $(7/90)/(1/60)$ ,  $p = 0.10$ ), while the strongest associations for cardiac irregularities and reproductive problems were found in the combined data (OR =  $(9/139)/(0/96)$ ,  $p = 0.0079$  and OR =  $(15/139)/(4/96)$ ,  $p = 0.053$ , respectively).

These associations imply that using the Haines Fairbanks Pipeline corridor for the collection of various resources increased the likelihood of certain health problems, including classic toxicological effects (reproductive problems and cardiac irregularities), as well as indicators of metabolic syndrome, as reviewed below. Herbicides had been

used in the HFP corridor, including the ingredients of Agent Orange, and subsequent dioxin exposure is the most reasonable and most likely explanation of these findings, although evidence is circumstantial. This chapter reviews the history of the Haines-Fairbanks Pipeline, and discusses other resources associated with the same general health problems, as well as the inferential knowledge derived from this section of the Northway Health Study (NHS).

These implications are well supported by the toxicological literature surrounding dioxin and dioxin-like chemicals. As with the cancer and thyroid associations, there seems to be a clustering of these reported problems among individuals born in the 1940s, suggesting an environmental vulnerability prior to using the pipeline corridor. The associations in our study do not begin to prove a cause and effect relationship and the issues are deeply complex, but inference that pipeline users were exposed to effective levels of dioxin is entirely reasonable. While insulin resistance and diabetes are well known for having important genetic risk factors, increasing evidence suggests that epigenetic mechanisms of environmental pollutants can partly explain the rise in these and various other disorders that have traditionally been ascribed to “genetics.” This possibility was suggested in the 1996 book *Our Stolen Future* (166), and has been reviewed more recently with extensive evidence (129, 167, 168).

### ***Haines-Fairbanks Pipeline History***

There is documentation of the use of the ingredients of Agent Orange in the HFP corridor, but it is limited to one sentence. A 1970 memo from the US Army Alaska states that 2,4-D (2,4-dichlorophenoxyacetic acid), and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) were among selective herbicides that had been “...used with a great degree of success... (169),” along with Tordon 101 (liquid) and Tordon 10K Pellets. The herbicides 2,4-D and 2,4,5-T were the two main ingredients in Esterone or Brush Killer, which was also known as Agent Orange. Both are toxic, but neither is persistent. However, 2,4,5-T was contaminated by the most toxic form of dioxin, TCDD (2,3,7,8-tetrachlorodibenzo-dioxin; see below), by its own production process (170). Formulations with 2,4,5-T were clearly used. How often, for how long, and the concentration of dioxin in each application (which was highly variable) cannot be known.

Other documentation surrounds the 1970 memo, and is briefly reviewed here. Both 2,4-D, and 2,4,5-T were on a 1963 Department of the Army list of approved pesticides and herbicides (171) that was distributed with a 1965 general directive regarding herbicide and pesticide use (172). Tordon formulations (liquid and pellets), that would be prescribed for use in 1968, were absent because the active ingredient (Picloram) was only introduced in 1963 (173). The pipeline had been in operation since 1955 and was likely to have visually obstructive brush within a few years of construction.

US Army Alaska technical specifications written in 1968 for the flight company contracting herbicide application along the HFP describe detailed instructions for dispersal (174). Tordon formulations, and 2,4-D were to be applied to the center 40 feet of the 50 foot right-of-way, and not exceed the boundaries for the stated purpose of not creating future liability by damaging adjacent forest. Communities, streams, and a fish hatchery near Fairbanks would also be avoided (174), perhaps reflecting the increased national awareness of the hazards of herbicides, although 2,4,5-T was not legally phased out until the 1970s.

In 2003, the Alaska District of the Army Corps of Engineers conducted a Herbicide Residue Survey and found no physical evidence that dioxin contaminated herbicides had been used in the Alaska section of the corridor. Soil samples had a low level suite of dioxins that would be typical of other sources, but no detectable levels of TCDD (175). An additional study commissioned by the Tanana Chiefs Conference found very low levels of TCDD in one sample (176). While dioxin is extremely persistent in the environment, this does not mean that it does not attenuate over decades (177). Beyond the disturbance of human use, especially in the 1970s and 80s, adsorption or ingestion by microbes, insects, and small mammals, as well as wind, bulldozers, and degradation can explain the general absence of TCDD in surface soils more than 30 years after the last application. (Bulldozers were used to remove the pipe for steel reclamation in 2001 (B. Sattler, Jan 17, 2010).) As any remaining pollution has likely moved into the food web, a study of small range mammals, and/or amphibians and raptors would be a better way to evaluate contemporary levels of biologically available dioxins in the pipeline corridor, but estimates of historic exposure would still not be possible (81, 178).



## Dioxin

The polychlorinated dibenzo-dioxins and the closely related polychlorinated dibenzo-furans are collectively referred to as dioxins or dioxin. The most notorious dioxin is TCDD (2,3,7,8-tetrachlorodibenzodioxin), but dioxin exists in mixtures. The word dioxin can refer to either TCDD itself, the family of dioxins and furans, or it may be intended to include these as well as the “dioxin-like” PCBs (179). Here, dioxin refers to the family, and the plural dioxins refers to the suite of dioxin and dioxin-like chemicals.

Dioxin is not produced intentionally, but rather results as a by-product from chemical processes where chlorine is present, such as the production of pesticides and the combustion of waste (152). Dioxin and dioxin-like chemicals are extremely lipophilic and persistent, and toxic in complex ways. Extensive effort has gone into assessing the risk of dioxins in the environment, as demonstrated by the centrality of TCDD in the Toxic Equivalency Factor (TEF) system (180) that was devised to quantify the risks of exposure to dioxin-like toxics. TCDD is ranked as 1, with other congeners (including the furans and dioxin-like PCBs) assigned a TEF that is meant to describe their relative toxicity. The limits of the category “dioxin-like” are not clearly established (181). A review of the TEF or Toxic Equivalency Quotient (TEQ) system is beyond the scope of this project, but it must be said that this attempt to simplify is unlikely to capture the complexity of the multiple and interactive mechanisms of dioxin toxicity (60, 182).

The literature regarding dioxin toxicity is extensive. Likewise, dioxins and other pollutants that act along some of the same biochemical cascades have been connected to the generalized health problems reported here, despite variation in methods and some inconsistency in findings, as briefly reviewed below. Studies of toxic effects related to endocrine function over the last 30 years have greatly improved our understanding of endocrine disrupting chemicals, and dioxin has been central to that research. A Google Scholar search of “dioxin” returns over 143,000 hits, with tens of thousands of papers on dioxin sources, levels, pathways, effects, and mechanisms of action—most thoroughly reviewed recently by the National Research Council (183).

## Associations with the Haines-Fairbanks Pipeline

### *Cardiac Irregularities*

Cardiac irregularities described by Northway residents included murmurs, arrhythmias, and one fatal case of Long QT (delayed repolarization of the heart (184); (Table 11)). Few medical details were reported and the observations were not necessarily diagnosed. Two childhood murmurs occurred before the pipeline was active so, as with other health patterns identified by the NHS, other exposures and factors were inevitably at play.

Table 11. All reported cardiac irregularities.				
Sex	Year of birth	Notes on irregular heartbeat	Other study conditions	Other notes
5F 4M	1939-1949	"beat funny" as child	high b pressure	
		long Q-T (cause of death)	diabetes low birth weight baby high b pressure	depression / anxiety gallbladder removed
		arrhythmia	breast cancer 2 stillborn 1 died as newborn malformed heart	
		heart flutter		
	1957-1966	murmur		
		irregular heartbeat	developmental disorder	
		irregular heartbeat		
		heart murmur when young		
		occasional murmur	thyroid problems when young gest diabetes high b pressure	allergies, asthma, depression / anxiety

These cardiac irregularities are consistent with developmental disorders that have been associated with dioxin and dioxin-like chemicals. Dioxin and dioxin-like chemicals have been documented as causal agents of congenital heart defects in animals (185, 186) and as a risk factors of cardiac malformation and dysfunction in

people (187). The only other resource associated with cardiac irregularities was FAA water use, which also began after the first reported murmur (1940s). Chlorinated byproducts of water treatment have been associated with cardiac malformations elsewhere (188), leaving the FAA-cardiac relationship unclear.

### ***Metabolic Disorders***

There were 50 metabolic disorders (high blood pressure (hbp), high cholesterol (cho), and blood glucose problems (bgp)) reported among 37 people in our data (Table 12). The undeniable facts of processed foods and modern vehicular travel have provided a nearly exclusive explanation for increasing rates of metabolism disorders in rural Alaska for many years. Concerns regarding these problems in Northway were understandably vague. Nonetheless, the inclusion of diabetes in our study was based on suspicions among the local steering committee. These suspicions are supported by two lines of evidence in the literature: findings that refute the general hypothesis that food quality and caloric imbalance can fully explain the phenomena of diabetes, obesity, and coronary heart disease in the broader context (189), as well as findings that identify multiple mechanisms and instances where contaminants thwart metabolic function, as briefly reviewed below.

All three of these metabolic problems have been clearly associated with the consumption of saturated fats (190, 191). This body of evidence is further supported by the apparent role of nutrition in epigenetic systemic programming (192). In our data, beef, with its higher saturated fat content than wild foods, was associated with a higher risk of high blood pressure and high cholesterol. We also found consistent negative associations between fish and high cholesterol, while negative associations with high blood pressure were weaker but also consistent. These findings seem to demonstrate another large body of evidence that fish consumption benefits arterial health (193) and glucose metabolism (194). Our findings are also consistent with rapidly expanding research (158, 195-201) that links dioxins with metabolic disorders, among other problems, via multiple complex and interactive mechanisms (58, 202-206). Recent prospective studies have demonstrated a causal link between endocrine disruptors and diabetes by documenting that exposure prior to diagnosis predicts an increased prevalence of both type 1 and type 2 diabetes (207, 208).

**Table 12.** All reported metabolic disorders

sex	YOB	Blood Glucose	CH	HB	other study conditions	other
1F 3M	before 1930	low blood sugar		x		angina
				x		heart attack
				x		ulcers, copd
		diabetes (elder onset)		x		
1F 5M	1930s	low blood sugar	x	x		asthma allergies
				x		respiratory tract
				x	prostate cancer	
			x	x		arthritis
				x	"heart beat funny" as child	
				x	skin and prostate cancer	
6F 7M	1940s		x	x		baby w/deformed feet
				x		allergies
			x	x		
				x		
			x			
		diabetes				
		diabetes		x	fatal long Q-T, lbw baby	depression/ anxiety, gallbladder removed
		diabetes		x		
				x		chronic obstructive pulmonary disease
				x		kidney stones
				x	breast and intestinal cancers	5 bypass'
		diabetes			breast cancer, 3 miscarriages	TB g daughter with thyroid problems
2F 4M	1950s		x	x		arthritis
				x		
				x		dev disabilities
				x		allergies (not as bad as used to be)
		diabetes				
		diabetes			diabetes	
			x	x		
1F 2M	1960s		x	x		
		gestational diabetes		x	undefined thyroid, murmur	gout
				x	undefined thyroid	allergies, asthma, depression / anxiety
1F 2M	1970s	diabetes				depression / anxiety
		diabetes '08				born lbw, milk allergies
1F 1M	1980s			x		
		gestational & prediabetes				

YOB = Year of Birth, CH = high (LDL) Cholesterol, HB = High Blood Pressure

Metabolic Syndrome is defined as a set of risk factors for type 2 diabetes that tend to occur together and are related to energy use within the body (209). The components of metabolic syndrome include high blood pressure, increased triglycerides, increased fasting glucose, decreased high-density lipoprotein (HDL) cholesterol, and abdominal obesity. Accompanied by some level of insulin resistance, as they generally are, three of these five disorders justify a diagnosis of metabolic syndrome (209). Metabolic syndrome can be considered a pre-diabetic state, or even the early stages of type 2 diabetes (210). Insulin resistance and related problems are highly complex and multifactorial—with diet, lifestyle, environmental, and genetic factors playing major roles in the etiology of disease (210).

The alteration of blood glucose regulation by dioxin has been recognized, if not understood, for decades. However, despite ample evidence of the critical relevance of these issues in Alaskan communities (211-219), the link between ubiquitous and hormonally active chemicals such as dioxin in biological tissue and epidemic rates of insulin resistance has been left out of the discussion (220, 221).

### ***Reproductive Problems***

The reproductive problems reported in this study varied from birth defects to sterility, and also included many unsuccessful pregnancies (Table 13). An underreporting of alcohol related reproductive problems is suspected, and those identified here are not likely to be alcohol related. Related problems showed a strong gender bias, in part because miscarriages, still births, and birth defects were attributed to the mother, perhaps inappropriately as paternal exposures may also play an important role in gestational success (222).

As with other studied health conditions, the excess of people born in the 1940s seems to imply there was some kind of fetal or childhood priming for these problems coincident with WWII activities. The strongest association with reproductive problems was FAA water, and FAA statistics are strengthened by an even split of users versus non-users. FAA water was used by the public from about 1960 into the 1980s. The association of chlorinated byproducts of water treatment with reproductive problems elsewhere (223) makes an FAA water contribution to reproductive problems plausible.

**Table 13. All Reported Reproductive Problems**

<b>Sex</b>	<b>YoB</b>	<b>Notes on reproductive problem</b>	<b>Other study conditions</b>	<b>Other notes</b>
2F	before 1940	excessive bleeding	breast cancer	
		miscarried twins	multiple myeloma	1 baby SIDS 9days
8F 2M	1940s	baby w/dformed feet	high cholesterol high blood pressure	
		baby died at birth, enlarged heart	multiple myeloma	
		irreg periods 2 premature births 1 with cerebral palsy	breast cancer thy since 1980s	daughter and her son cncr
		low birth weight baby	breast cancer	1 baby SIDS (different baby)
		low birth weight baby	diabetes high blood pressure fatal long Q-T	depression/ anxiety gallbladder removed
		2 stillborn, 1 newborn death - malformed heart	breast cancer arrythmia	
		excessive bleeding		allergies intestinal cysts
		sterile		
		sterile		
		3 miscarriages	breast cancer diabetes	
4F	1950s	excessive bleeding		
		premature births	breast cancer	
		baby with developmental disorder	irregular heartbeat	
		baby with hydroencephaly, no brain stem		
3F 1M	1960s	2 miscarriages		
		sterile		
		excessive bleeding	hypothyroid	allergies
		ovarian polyps		

However, of the 20 people reporting reproductive problems, 16 had used FAA water, 17 had consumed fish regularly, 15 had used the Haines Fairbanks Pipeline corridor and 12 had reportedly used all three. A much lower proportion of the total (73 of 325) had reported using these three. Multiple exposures and interactive effects are implied but not quantifiable. Reproductive problems like those documented here are among the most well studied effects of dioxin and dioxin-like chemicals in animal and human studies (224-229).

### **Conclusion**

Children and teenagers who used the pipeline may have been most vulnerable to life long effects, but at least some individuals reporting associated health problems were adults in the 1970s. None of the exposures identified by this dissertation occurred in isolation. Rather, exposures happened as they do outside of the laboratory: as highly variable mixtures. Knowledge of the risks can help parents and communities take measures to protect against and compensate for subtle developmental problems.

Weaker statistical associations among current residents imply that other facets of modern life such as processed foods, insufficient exercise, and probably household chemicals (230, 231), are increasingly important contributors to metabolic disorders in Northway. While new exposures do not negate historic risks, typical consumer products of today (230, 232) are more likely than military waste to be current toxicological hazards. Many relatively new household chemicals, from brominated flame-retardants to phthalates, are also classified as “obesogens” and are well documented to interfere with endocrine and metabolic function (233), as further discussed below.

Our study did not identify diagnostic cases of metabolic syndrome, but a full study of use of the Haines-Fairbanks Pipeline across the Upper Tanana is warranted. Such research would have to be locally controlled, with support from federal and state agencies, including the University of Alaska. The need for answers in communities such as Northway is compelling and barriers to data collection are substantial, even for community members. This study successfully identified and reasonably explained very general associations between certain resources and illnesses, but the derived knowledge is inferential and remains scientifically hypothetical.

## 5. UNCERTAINTY AND HUMAN ENDOCRINE DISRUPTION

### Introduction

This chapter explores multiple sources of uncertainty within studies of historic exposures and health effects, and begins with a brief review of the limitations of the Northway Health Study (NHS). Historic exposure to environmental contaminants was, in some cases, inevitable but none were documented. The only available method to estimate historic exposure is by the subjective proxy of resource use over time. For these findings to be most meaningful, the resource data would have to be scaled with respect to life-stage timing and extent of each resource used. The NHS lacked detailed medical information, such as year and age at diagnosis, and verification with medical records. Much of the information is second hand. Control for and study of genetic risk factors would be ideal, since genetic connections to health and susceptibilities to illness, are deep and inextricable (234). Many suspected and known exposures are not considered in this study. Because each comparison was independent those uncontrolled factors include other studied resources as well as various historic water supplies, and occupational or household chemicals such as fuels, solvents, other petrochemicals, chlorine bleach, illicit drugs, pharmaceuticals, tobacco, and alcohol. This lack of control undermines definitive conclusions, but does not preclude a meaningful investigation.

This chapter, which frames the situation in Northway as a case study of endocrine disruption, rests on the uncomfortable notion that conservative interpretations requiring 95% certainty are dangerous due to the likelihood of false negative results. Science has earned a rigorous reputation with a high demand for avoiding false negative findings: seeing an effect when there has not in fact been one. However, 95% certainty of all details is rare in retrospective epidemiology, and not necessarily possible no matter how true connections might be. In these circumstances, a more cautious interpretation of evidence is appropriate (235). For instance, the strong implication that people who spent time in the Haines Fairbanks Pipeline corridor and used FAA water have an elevated risk of multiple disorders should not be ignored, although some statistics are non-significant and neither exposure can be quantified.



## Endocrine Disruption

“Endocrine disruption” (ED) is a very general explanation of myriad diverse disorders affecting both animal and human populations via interference with hormones and other chemical signals by complex and variable mixtures of synthetic (and natural) compounds found in biological tissue. ED as a general explanation of apparent phenomena is relatively young. While patterns of endocrine disruption in human and wild populations have been documented and ED has gained widespread scientific acceptance with a tremendous weight of evidence, the thesis is still in its theoretically formative stage. The bewildering complexity of endocrine function and other chemical signaling, as perturbed by natural and synthetic factors, has yet to be captured by clearly defined boundaries, terminology, and principles (236). However, by 1996, extensive evidence was documented and popularized by the book Our Stolen Future (237). As those authors acknowledged, Rachael Carson had pioneered the field of environmental hormones thirty years earlier in her book Silent Spring (238).

The hormonal activity of various synthetic chemicals has been known for many decades, and many drugs have been designed for the purpose of endocrine activity (239). Endocrine disrupting chemicals (EDCs) come from a broad range of chemical classes, but the organochlorines (OCs), including PCBs, pesticides such as DDT, and dioxin, are the most well documented (240-242). Diethylstilbestrol (DES) was an intentional hormone prescribed for the prevention of miscarriage (1940~1970) with disastrous results for the offspring including vaginal carcinoma and reproductive abnormalities. Although DES eventually provided a clear signal of endocrine disruption, the recognition of various developmental defects was delayed until those cohorts reached adulthood (58, 243).

Since then, laboratory research has produced extensive empirical data regarding the subtle and growing threats of endocrine disrupting chemicals (244). The implications of ubiquitous exposure to contaminant levels that were not analytically detectable twenty years ago have only been widely appreciated in recent years. The Endocrine Society’s 2009 Scientific Statement “Endocrine Disrupting Chemicals” is one of many documents that help to clarify evident risks to the environmental health of humankind as they are currently understood (58). The ES statement reviews evidence that various contaminants that interfere with endocrine signaling are biologically active at

environmentally relevant levels, especially during development. Their thesis, which has been postulated elsewhere (59, 110, 214, 245-248), is that such contaminants have begun to contribute to many health problems, especially cancer and reproductive-, thyroid-, neurological-, and metabolic problems—across human populations with high variability. The document begins by raising five “Important issues in endocrine disruption (58).” These issues are paraphrased, briefly discussed, and interpreted with respect to the Northway Health Study in the following two sections.

### ***Important Issues in Endocrine Disruption***

#### **\* Timing of exposure**

Adults have much resilience to short-term toxic exposure. However, early structural and programmatic development of cells into tissues and organs is dependent on delicate interactions between maternal and fetal hormones, and the environment. Even slight alterations to homeostasis during critical periods of gestation can have dramatic effects on offspring. Developmental vulnerabilities continue through puberty, especially for the brain.

#### **\* Latency from exposure**

Developmental effects can be manifested in adulthood. This is known as the developmental basis of adult disease and was first recognized with respect to nutritional deficits, low birth weight, and obesity.

#### **\* Importance of mixtures**

Exposure to environmental toxics occurs in combinations that are personally unique and vary from conception through death. Effects can be additive or synergistic.

#### **\* Nontraditional dose-response dynamics**

Often with no apparent threshold (meaning any exposure at all) EDCs can induce endocrine irregularities, particularly during sensitive periods of development. EDCs often exhibit nonmonotonic dose-response curves, with a U or inverted U shape, meaning that “lower doses may even exert more potent effects than higher doses.” Such relationships have long been known for natural hormone function.

✱ Transgenerational, epigenetic effects

Epigenetic mechanisms of germline alteration that modify genetic expression and programming but not DNA itself have been elucidated, in addition to direct genomic effects, as capable of transferring effects through multiple generations.

The purpose here is not to review the toxicological evidence of endocrine disrupting chemicals (EDCs), as the ES statement and many other documents have done. Rather, the following narrative describes the conceptual basis for analyzing the NHS as a case study of endocrine disruption. All of the following generalizations are well reviewed and thoroughly referenced in the ES statement (58):

Vastly expanded research has enabled the elucidation of multiple mechanisms that are shared, with variability, across species in recent decades. EDCs such as PCBs and other dioxin-like chemicals can have activational effects (changes to homeostasis in adulthood) and organizational effects (structural and functional alterations that take place during development and are diverse and generally irreversible). Animal studies are unequivocal. It's not that EDCs can interfere with chemical signaling and normal development, they generally do and with high variability due to numerous factors. The mechanisms (including but not limited to membrane and nuclear receptor activation or blocking, the up or down regulation of receptor synthesis, interference with the transport and metabolism of natural hormones, and genomic and epigenetic alterations) are deeply complex and predict diverse outcomes. Interferences can occur at any point, or multiple points, in the life cycle of a hormone, such as synthesis, transport, action, or metabolism. In particular, "cross talk" between an organism's biological systems means that an effect on one system (thyroid, metabolic, reproductive) often entails an effect on others, depending on the exact life-stage timing of the interactions.

Many reproductive problems, cancers, and an increasing variety of immune, metabolic, and neurologic disorders, apparently demonstrate the capacity of EDCs to disrupt lifelong function in developmentally exposed organisms, including people. The document includes concise review of mechanistic and clinical evidence regarding breast cancer, and reproductive-, metabolic-, and thyroid function, with some inclusion of as yet poorly understood immune and inflammatory pathways in the discussion. The ubiquity of

variable complex mixtures of EDCs in biological tissue means that every child born today is at unknown risk.

Hormones and other chemical signals are multifunctional and redundant, meaning they each do many things and many do some of the same things, and often act at levels in the ng/g range.. Likewise, EDCs are most often toxic through multiple mechanisms with multiple outcomes, including at low levels. The ES authors suggest that all biological systems are vulnerable, particularly via neuroendocrine signaling, although the strength of evidence that EDCs are now having widespread effects on human health varies considerably. Importantly, the strength of evidence depends not only on the occurrence of effects, but also on whether well-designed research has been conducted to document it. While continued collection of evidence is recommended, a new paradigm that recognizes and anticipates complexity is called for (249). Polycyclic Aromatic Hydrocarbons (PAHs) are not mentioned in the ES statement but the petroleum constituents of concern in Moose Creek, and their carcinogenic endocrine activity, have been reviewed elsewhere (138, 246, 250, 251).

### ***Important Issues Exemplified in Northway***

Northway residents had identified the use of Moose Creek as a cancer risk by the 1980s. Other results of the Northway Health Study were not as clearly expected but neither was there surprise. Multiple historic exposure pathways that cannot be quantified, and inevitably occurred with variation across time and households, were identified by the Northway Wild Food Study (Table 14). Numerous unknowns contribute to inherent uncertainty that precludes the establishment of cause and effect links in small human populations (252). Nonetheless, it is reasonable to frame the Northway data (Table 15) as a case study of endocrine disruption in people. Indeed, the issues outlined above can explain certain patterns in Northway

<b>Table 14. Resources evaluated for association with health problems.</b>		
<b>Resource</b>	<b>Primary Known Concern (suspected)</b>	<b>Time Range of Use <sup>g</sup></b>
MC Water <sup>a</sup>	petroleum, (polychlorinated biphenyls, pesticides )	pre-war ~ 1980s
FAA Water <sup>b</sup>	chlorinated byproducts of disinfection (unknown)	1960s-1980s
Whitefish <sup>c</sup>	polychlorinated biphenyls, pesticides, mercury	pre-war – present (less now)
Beef (store bought)	saturated fat (hormones, antibiotics, unknown)	1970s-present (first in 1950s, more now)
Caribou <sup>d</sup>	(radioactive fallout)	1950s – 1970s
Roadside Roots <sup>e</sup>	lead (Pb)	1950s – present (much less now)
HFP <sup>f</sup>	herbicides including 2,4,5-T	1970s~2000
<sup>a</sup> Moose Creek moves East from the Airstrip, roughly parallel to Northway Road <sup>b</sup> The Federal Aviation Administration had a public-use well and tank at the airport. <sup>c</sup> Broad and Humpback Whitefish ( <i>Coregonus nasus</i> , and <i>C. oidschian</i> ) <sup>d</sup> Caribou ( <i>Rangifer tarandus</i> ) consumption in the era of above ground nuclear weapons test was a possible concern. <sup>e</sup> Edible Roots, or “Indian Potato” ( <i>Hydysarum alpinum</i> and <i>H. hedysaroides</i> ). <sup>f</sup> The Haines Fairbanks Pipeline corridor was used for collecting many resources <sup>g</sup> Reflects my understanding of resource use as summarized in Appendix A.		

**Table 15.** Reported Health Problems and Identified Associations.

<b>Health Problem</b>	<b>n</b>	<b>Significant</b> ( $p < 0.05$ ) ( <i>negative</i> )	<b>Non-significant</b> ( $p < 0.10$ ) ( <i>negative</i> )
Cancer	35	MC <sup>a,c</sup> , Fish <sup>c</sup>	FAA <sup>c</sup> , Roots <sup>c</sup> , Fish <sup>b</sup> , MC <sup>b</sup>
Thyroid problem	13	Fish <sup>b,c</sup>	HFP <sup>b</sup> , Beef <sup>c</sup>
Repro problem	20	FAA <sup>a,c</sup>	HFP <sup>c</sup>
Cardiac irreg	9	HFP <sup>a,c</sup>	FAA <sup>c</sup>
High blood press	29	Beef <sup>a,c</sup> , HFP <sup>a,c</sup>	(fish <sup>a</sup> )
High cholesterol	8	FAA <sup>a</sup> , HFP <sup>a</sup> (roots <sup>a</sup> , fish <sup>a</sup> )	FAA <sup>c</sup> , Beef <sup>a,c</sup> , HFP <sup>c</sup> (fish <sup>c</sup> )
Blood glucose reg	13	none	HFP <sup>a</sup>

<sup>a</sup> Historic households data ; <sup>b</sup> Current households data; <sup>c</sup> Combined data; MC = Moose Creek; Fish = whitefish; FAA = water from FAA facility; HFP = various resources from the Haines-Fairbanks Pipeline corridor.

#### \* Timing of exposure

One third of the 89 individuals reporting 127 categorical health problems were born in the late 1930s or 1940s (Table 16). The coincidence of their youth with WWII military activity implies some relationship, especially considering that among all participants, the plurality are in the next youngest age group. When taken together with the inference that exposure to petroleum and pesticides probably began immediately from the construction, from operation of an asphalt plant at Moose Creek near the airstrip, and from the application of pesticides along Northway Road for mosquito control. Persistent pesticide and PCB exposure would have continued over years as

they magnified in the food web (81). Dioxin exposure implied by this study (in the Haines Fairbanks Pipeline corridor) did not occur until the 1970s and 1980s. There is no intent to suggest that every reported health condition is attributable to military waste and, indeed, people are more vulnerable to disease as we age. However, some interpretations find that these kinds of problems are not a normal part of the aging process, but rather reflect the toxic environment we experience from conception onward.

<b>Table 16. Years of Birth. Years of birth of study participants and those reporting at least one categorical health problem.</b>				
<b>Year of Birth<sup>a</sup></b>	<b>2010 Northway census population<sup>b</sup></b>	<b># reporting problem</b>	<b># participants</b>	<b>%</b>
before 1930	0	15	26	58
1930-1949	33	39	83	47
1950-1969	(1950-1974) 90	28	103	27
1970-1999	(1975-1990) 92	6	47	13
since 2000	(since 1990) 149	1	66	1.5
<sup>a</sup> Some years of birth were estimated, such that they fell within these groups.				
<sup>b</sup> Northway population data from (14, 15).				

✱ Latency of exposure

Few of the 127 categorical conditions were noted as diagnosed in childhood (birth defects, low birth weight, and lost pregnancies were ranked as a woman's reproductive problem). All cancers included in the analysis were diagnosed in adulthood, including the youngest reported, a 39 years old woman with breast cancer. One childhood leukemia was said to have occurred in the late 1990s. This was not verified or included, as the family has moved from Northway. Two of the cardiac irregularities were reported in small children—beginning prior to the construction of the Haines-Fairbanks Pipeline. Some of the thyroid problems were diagnosed in children, and one 2010 adolescent diagnosis is not included in the study.

✱ The importance of mixtures

While the NHS had small numbers of people, many of whom used some of the same resources, interplay between contaminants is implied by multiple associations with each health problem. In particular, fish (PCBs, pesticides), FAA water (chlorinated byproducts), and the pipeline corridor (dioxin) seem to have interacted for adverse outcomes. The difficulty of distinguishing between cross correlation and contaminant interaction is discussed below.

✱ Nontraditional dose-response dynamics

The simplicity of the NHS precludes any potential capacity to investigate this aspect of endocrine disruption because of the lack of scaling of resource uses (data on a spectrum, rather than a dichotomy).

✱ Transgenerational, epigenetic effects

While this issue was not investigated by the NHS, and young families were underrepresented, several of the reported thyroid problems were diagnosed in youth. One girl was diagnosed at birth and one required surgery at age 14. Two other girls with reported thyroid problems were not included because their mother's family had left Northway when she was a baby. Questions regarding the adult onset of disease for children born after the remediation, which occurred mostly in the mid 1990s, will require more time.

**Cross correlation or contaminant interaction?**

One complicating aspect of the NHS is the fact that people who used one wild resource often used several, ensuring an overlap of cohort constituencies. The difficulties of distinguishing between cross correlation of resource use and the possible interaction of contaminants are substantial. The issue, however, is worth discussion because of the likelihood of contaminant interaction for people who consumed more than one resource with low level contamination. As stated earlier, users of three resources tended to have a higher risk of several studied health conditions (Table 17).



**Table 17.** Implicated Contributing Factors. Odds Ratio<sup>a</sup> and p-value for each comparison. Users of these resources show a higher incidence, sometimes slight, for many of the health problem categories. Comparisons where OR < 1 omitted.

	Cancer (35)	Thyroid (13)	Blood glu (13)	Cardiac irreg (9)	Repro (20)	High cho (8)	High bld pres (29)
FAA	<u>19/126</u> 10/127 0.054	<u>8/126</u> 3/127 0.13	<u>8/126</u> 4/127 0.13	<u>7/126</u> 2/127 0.084	<u>16/126</u> 4/127 <b>0.0042</b>	<u>6/126</u> 1/127 0.060	<u>16/126</u> 11/127
FISH	<u>31/240</u> 4/75 <b>0.047</b>	<u>13/240</u> 0/75 <b>0.030</b>	<u>11/240</u> 2/75 0.35	<u>8/240</u> 1/75 0.31	<u>17/240</u> 3/75 0.24		
HFP		<u>7/139</u> 4/96 0.50	<u>8/139</u> 3/96	<u>9/139</u> 0/96 <b>0.0079</b>	<u>15/139</u> 4/96 0.053	<u>7/139</u> 1/96 0.094	<u>21/139</u> 6/96 <b>0.027</b>

<sup>a</sup>Odds Ratio = incidence per users / incidence per non-users.

Among 89 people with at least one reported categorical health problem, implicated resource uses were reported as follows: 76 ate fish; 51 used FAA water; 49 used the Haines Fairbanks Pipeline Corridor; and 43 used Moose Creek as a source of drinking water. Four out of the 89 people did not report using any of those resources regularly; 15 reported using one of these sources; 28 reported two; 20 reported three; and 22 reported using all four. The total number of specified resources used among all participants and among those reporting at least one illness is summarized in Table 18. Most striking is that essentially half of people reporting four resource uses also reported at least one health problem. The increased relative risk with multiple resource uses implies interaction between contaminants, though whether additive or synergistic remains unclear and there is no evidence of biochemical mechanisms.

**Table 18.** Number (#) of implicated resources. Implicated\* resource use among all participants (n = 325) and those reporting at least one health problem (n = 89).

#	/325	%	/89	%	Relative risk
none	44	13.54%	4	4.49%	4/44 = 9.3%
1	80	24.62%	15	16.85%	15/80 = 18.8%
2	108	33.23%	28	31.46%	28/108 = 25.9%
3	47	14.46%	20	22.47%	20/47 = 42.5%
4	46	14.15%	22	24.72%	22/46 = 47.8%

\* Moose Creek, Whitefish, FAA water, and the HFP corridor.

### ***Suggested Contributing Factors***

#### *Whitefish*

Although both the numbers of fish and fishing have declined over the decades, whitefish remain an important source of protein in Northway (154). Fish consumption was the strongest and only significant association with thyroid problems, although consumption of store bought beef and FAA water use were weakly associated. Associations between fish and high blood pressure and cholesterol were consistently negative, the users showing a decreased risk. These statistics have variable strength and apparently weaken over time, most likely because people do not eat as much fish anymore. In addition to the significantly higher risk for cancer and thyroid problems, whitefish consumers had a generally higher risk for several of the health problems we studied that would not be expected from a fish diet (85).

The data show fish consumers have a slightly higher risk (though often non-significant) for blood sugar problems, cardiac irregularities, and reproductive problems, which may be explained by the facts that: 1) any chemical exposure from fish (PAHs, PCBs, DDT, other pesticides, and their metabolites) was experienced in combination with other exposures at the time, as well as with additional exposures over the years; 2) nearly everyone ate fish early-on (prior to World War II through the 1960s); and 3) subtle repercussions of sub-clinical thyroid dysfunction are difficult to identify, even in massive population studies (253). The subtle repercussions of population-wide perturbation of thyroid hormones, even among people without diagnosed thyroid problems, may have interfered with structural and functional development of reproductive, cardiovascular,

and metabolic systems in the children of fish consumers, putting them at higher risk later in life (157, 254-256). Indeed, such a complex array of diverse but related outcomes that also depended upon subsequent exposures might even be expected. Of course, each individual ate different amounts of fish and that varied through their life. Likewise, historic levels of PCBs, DDT, their metabolites, and other endocrine disruptors in fish cannot be determined.

Limited data are available, and are reviewed in Chapter 1. Briefly, DDE was the only OC contaminant found in each of nine Burbot livers collected in 2000, ranging from 0.0014 to 0.028 µg/g (wet weight) (106). One whitefish was tested for PCBs in the Wild Food Study of this project. The fish was taken at the confluence of Moose Creek and Fish Creek, and tested at 0.246 ng/g (wet weight, sum of 18 congeners; average of duplicates; Chapter 1). Two whitefish were found to have 0.06 and 0.15 µg/g mercury. The toxicology of low doses is complex and reviewed in the ES statement (5).

#### *FAA Water*

Water from the tank and well at the Federal Aviation Administration facility (1960s-1980s) was used by half of all participants thereby strengthening statistics. In each dataset, people reporting consumption of FAA water showed a higher risk for each health problem, though sometimes very slight and only occasionally significant ( $p < 0.05$ ; Table 17). Some of the statistics are strongest in the combined data (cancer, irregular heartbeat, reproductive problems and high blood pressure), but blood sugar problems, and high cholesterol statistics were strongest among participating historic households (data not shown). The tank was described as heavily chlorinated and presumably contained chlorinated byproducts of treatment, and perhaps other contaminants, that could have contributed to these problems (Chapter 2).

#### *The Haines-Fairbanks Pipeline Corridor*

The Haines Fairbanks Pipeline Corridor was a popular place for collecting or accessing a variety of resources for over 20 years after deactivation in 1973. Alder and willow shrubs took decades to grow back, but raspberry bushes were prolific. Adjacent spruce trees sent out new root shoots that were ideal for basketry and the corridor was also used for traveling to neighbors, hunting, and camping. The history of herbicide use,

including the ingredients of Agent Orange, in the HFP corridor is supported by limited documentation, as reviewed in Chapter 4.

### **Multiple Complex Factors**

#### ***Cancer: Moose Creek Water, Fish, FAA Water, and Edible Roots***

Cancer is a very common health concern among Alaska Natives (2), including people in the Upper Tanana (4). Tobacco use in Northway is still common, and Northway residents understand that smoking can lead to cancer. However, historic pollution of Moose Creek with petroleum and other carcinogenic organic pollutants is also a matter of fact (13, 43), and provides a more reasonable explanation for significantly higher cancer rates among participants who used the creek as a primary water source. While there is no reason to believe people on Moose Creek smoked, or smoked inside, more than other people, smokers from Moose Creek, and their families, seem to still have the highest risk. Of five breast cancers diagnosed during the course of this study (since 2004), all were found in women who grew up drinking Moose Creek water and who were smokers or former smokers. During that same time period two cases of lung cancer were diagnosed in smokers, one of whom lived on MC as a child.

All MC families reported eating fish and about half of fish eaters reported using MC water. Until the 1970s, whitefish were generally harvested from Fish Creek, a tributary to Moose Creek. Whitefish consumption was also significantly associated with cancer, though with less statistical strength than Moose Creek, which leaves at least two unresolved issues: 1) possible interaction between PAHs and more persistent contaminants like DDT and PCBs that are still found in burbot livers (106); and 2) residual uncertainty about the safety of an important traditional food and source of protein. Two additional resources were significantly associated with cancer, which do not seem entirely explained by cross correlation: FAA water and edible roots found along the road. Cancer was the only positive association with roots, which were identified as a pathway for lead (Pb) in this study (Chapter 2).

***Metabolic Disorders: Haines-Fairbanks Pipeline corridor and FAA Water***

Metabolic disorders such as diabetes have been clearly associated with and almost exclusively explained by the consumption of processed foods, vulnerable genes, and a decline in physical activity (220). Alcohol and tobacco use also increase vulnerability to these and other disorders. However, metabolism disorders and their general association with use of the Haines-Fairbanks Pipeline corridor presented perhaps the most important findings in the NHS, in part because they were least expected and are therefore the most intriguing with respect to future research directions.

Despite the inherent uncertainty of such limited historical epidemiology, these findings, along with knowledge that the chemical 2,4,5-T was sprayed in the pipeline corridor (169), are consistent with a growing body of literature that suggests dioxins, dioxin-like chemicals, and a variety of other “obesogens” that are now ubiquitous in biological tissue are contributing to the global and circumpolar rise in metabolism disorders (199, 206, 219, 257-259).

Metabolic syndrome, a cluster of disorders related to how the body processes nutrients and energy is characterized by at least three of the following: high blood glucose, high LDL (low density lipoprotein) cholesterol, and high blood pressure, as well as elevated triglycerides, altered blood lipid profiles, and abdominal obesity (209). These disorders tend to accompany insulin resistance and are known as risk factors for type II diabetes. Dioxin, which contaminated the 2,4,5-T component of Agent Orange (Chapter 4), has been implicated in metabolic disorders in people, as first evidenced by Vietnam Veterans exposed to the herbicide (260). Since then, laboratory-animal studies have demonstrated the ability of low-level dioxin exposure to impair metabolic function, especially during development, while multiple human studies have documented strong associations between exposure levels and related problems (183).

One 2006 study used serum obtained from Operation Ranch Hand veterans (veterans exposed to Agent Orange in Vietnam) and other soldiers deployed to SE Asia to establish molecular evidence of exposure (261). The most sensitive and reliable biomarker of exposure they found was a ratio of two biochemicals: a glucose transporter and a nuclear transcription factor. This biomarker is a recognized indicator of inflammation and was found to show

... significant correlations to serum dioxin residues and to fasting glucose among those in the Ranch Hand group and, surprisingly, even in the comparison group, who have low levels of dioxin comparable to the general public. Such a correlation in the comparison group was particularly significant among those with known risk factors such as obesity and family history of diabetes (261).

More recent prospective studies have likewise established the capacity of certain endocrine disruptors to contribute to diabetes in people (207, 208). Various developmental mechanisms of metabolic disruption are reviewed in the ES statement, especially those occurring along steroidal and inflammatory pathways. Although multi-generational aspects are not addressed specifically for metabolic disorders they have been reviewed elsewhere (233), and the important issues of endocrine disruption, described earlier, apply.

### **implications Regarding Neurological Development**

The likelihood of an increased risk for neurological disorders such as learning disabilities and attention deficits was not directly addressed by this study. Concerns were raised by several individuals during initial interviews; however, the barriers to collecting such sensitive information are substantial and it was not queried. The concerns were supported by these three lines of evidence: 1) the documented presence of DDT and PCBs in fish, and lead (Pb) in edible roots from along the road (Chapter 1), 2) toxicological literature surrounding the complex dependence of the developing neurological system to maternal thyroid function and related toxic effects of these compounds (140, 262), and 3) the likelihood of historic and possibly ongoing low-level population-wide thyroid disruption described above in concurrence with unknown historic exposure to lead from roadside roots (as well as ammunition, plumbing, tobacco smoke, paints chips, etc..)

While many of Alaska's communities cannot be accessed by road, most had a small local road system for decades before lead (Pb) was banned from fuel products. Exposure to lead from roadside roots, and its possible association with developmental disorders, such as learning or attention deficits, has not been studied in Alaska, despite

the near state-wide distribution and popularity of “Indian Potato” (263). The strong preference of the plant for coarse, well drained substrate explains its abundance along roadsides. While the author is unaware of how Indian Potatoes are gathered in other communities, it is logical that root abundance and ease of picking would make roadside collection more convenient than river banks in many locations. Investigation could begin by surveying communities for the extent of local use.

Just as smoking and cancer are clearly and obviously connected, alcohol is neurotoxic and clearly the major source of social problems in rural Alaska. However, as with tobacco, the subtle effects of low level chronic exposures should be considered. Given the lack of threshold for gender specific neurotoxic effects of lead (264, 265) and endocrine disruptors in general (110), and the association of neurotoxics with aggression and recidivism (266) as well as poor impulse control, the possibility that exposure has contributed to social problems that are generally attributed to substance abuse needs investigation (267). Any such research would be extremely challenging and would require a strong measure of local control.

### **Sex Ratio**

Sex ratio alteration is an example of how toxic effects can exert an influence on probabilities rather than initiating or promoting an actual illness. Sex ratio alteration can be considered a sentinel of environmental endocrine disruption (59). For example, a heavily polluted First Nation community in Canada has the most severely skewed sex ratio documented in the world (268). A legal review of the situation demonstrates the inadequacy of a system that depends on the establishment of physical injury to individual bodies as a basis for “harm” and compensatory response (70). The analysis explores theoretical and legal issues surrounding sex ratio skewing by toxic exposure. If fewer boys are born, who is injured? Is it the boys not born, the girls with no boyfriends, or the parents who were denied the natural probability of having a boy? While the individual pollutants that this community is exposed to fall within “allowable limits” for the surrounding industries, the daunting prospect of extinction is nonetheless a deep threat to the local population (269).

Population statistics are uncertain in small populations, but given the circumstances in Northway an evaluation of sex ratio is appropriate. Among participants in the NHS, there were 73 reported parents who were in the Northway area during the time that use of the HFP corridor was popular, as shown in Table 19. The numbers are small, especially of non-HFP users. The children of the males and females in these cohorts partially overlap, since some of the children reported were reported by both their mother and their father. The difference between these groups is statistically weak, but the p-value of a difference between the sex ratio born to HFP parents compared to what would be expected from statewide data of the same time period is 0.11 (two tailed Fisher's Exact test in SAS), arguably indicating some 89% likelihood of a difference. Data from the NHS are limited, and the numbers are too small for robust statistics, but publicly available data indicate a skewing of sex ratio toward more females.

<b>Table 19. Sex ratio of births to users and non-users of the Haines-Fairbanks Pipeline.</b>				
	n	# boys	# girls	M/F ratio
W non-HFP users	9	24	18	1.33
M non-HFP users	6	7	6	1.17
W HFP users	32	62	70	0.89
M HFP users	26	49	62	0.79
AK Expected <sup>a</sup>	(for 111 children)	57	54	1.05
<sup>a</sup> AK expected Male:Female birth ratio of 1.05 obtained from data provided by Alaska Division of Vital Statistics (270).				

Similar statistics are derived from three other sets of data that were used to investigate sex ratio. None demonstrate a consistent significant difference, but each suggests an historically altered sex ratio (All comparisons conducted as two tail Fishers

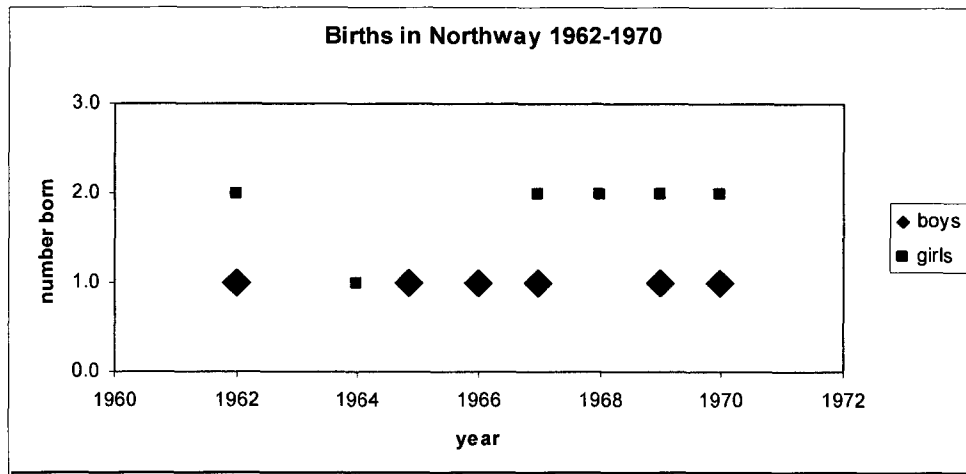


from 5 to 16 years earlier, the time scale of available data is very different, and cohorts overlap from one year to the next. The ratio is only significantly different from what would be expected by statewide data in the school year 2005-2006 ( $p$ -value = 0.031).

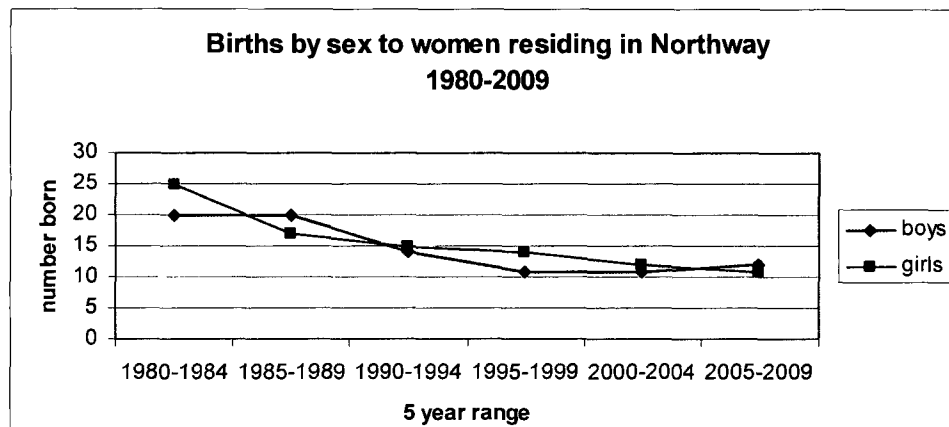
Though statistically limited, the implication of these ratios is very important. If the 1960s data are representative, which is likely but not assured, there may have been a very dramatic skewing before reliable records were kept. No births were recorded in Northway in 1963, 1970, or after, but later records were kept for women residing in Northway. There is an apparent decline in births since 1980, as well as an apparent evening of sex ratio. How much the different exposures had to do with these trends is unclear, but out-migration to larger cities is undoubtedly a factor (272, 273). Additionally, males are known to be more prone to accidents (274, 275). According to 2010 census data, 62.6 percent of the 361 person population is female (14, 15). Although sex ratio was not a concern raised during interviews, note of the evening ratio of births is welcomed by Northway residents.

### **One Little Girl**

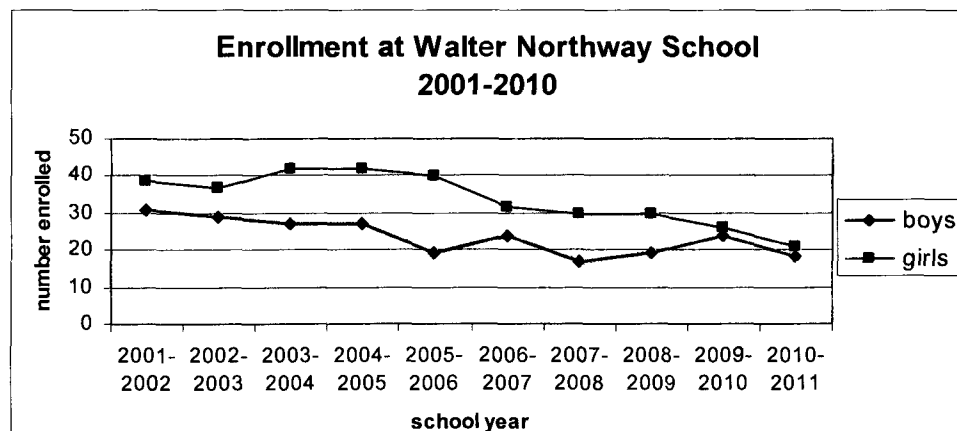
While the demonstration of patterns is a critical function of documenting the manifestations of endocrine disruption, personal stories get lost in numbers. One noteworthy case is a ten year old girl with severe allergy and skin problems. Her family participated in the study, but consistent information about allergies and other autoimmune problems was not collected, so she is not among the 89 people with analyzed illnesses. This child is isolated from other children by her skin. The condition is not contagious, but she should not perspire or get dirty. Additionally, her inflamed “breakouts” sometimes makes her a target for ridicule. She cannot eat many common foods. The prescribed treatment is topically applied steroids, but the medication provides marginal relief for her chronic itching and the prospect of side effects worries her parents. The family has lived between the Alaska Highway and the Haines-Fairbanks Pipeline corridor all her life. This is just one example of unresolved issues.



**Figure 9a.** Births in Northway (1962-1970).



**Figure 9b.** Births to Women Residing in Northway (1980-2009).



**Figure 9c.** School enrollment data by gender (2001/02-2010/11).

## Conclusion

The complexity of these issues is daunting, but toxicological research has accumulated extensive evidence that biologically active pollution threatens human health in complex ways that predict diverse (inconsistent) outcomes. Given the preclusion of controlled human experiments by appropriate ethical norms, there are three primary lines of evidence to evaluate the risks of chemicals to people: occupational, accidental, and laboratory data. Each has severe limitations in terms of discovering the effects of low dose chronic ecological exposures (72, 252, 276). In particular, a focus on working adults (usually male), a lack of background data, and interspecies variation, respectively, make these lines of evidence incomplete and inevitably inconclusive. Far from meaning that ecological and food related exposures are insignificant, there has been a deep underestimation of the threats posed by exposures that women of child bearing age experience everyday. Evidence of a paradigm shift in toxicology continues to mount (277) and the problem has been recognized by the National Institutes of Health (244).

Meanwhile, in many communities, historic releases of toxic waste amount to uncontrolled and undocumented experiments of exposure that can be expected to have had effects. Recoverable evidence of exposure or harm is not likely to be definitive, but it is likely to be informative to both the people who experienced it and to those interested in understanding the role of low-level ecological exposures in the complex etiology of disease. The use of inferential knowledge among Northway residents is reasonable, and yet, still, frustrating for the continuing lack of definitive proof. More broadly, the public health implications are also significant and joins a vast body of literature that implies, but can never prove, the danger of population-wide exposure to endocrine disrupting chemicals.

People in Northway are not comforted to learn that their concerns, as real and legitimate as they were and continue to be, have been matched by similar toxicological characterization of many chemicals that come into their homes via consumer products. How is it, they wonder, that humanity has allowed the widespread pollution of our bodies with so many dangerous chemicals for so long? This author can only answer that the problem is not a lack of evidence, but rather a political unwillingness to confront extensive but complex evidence.

## 6. CONFRONTING INJUSTICE WITH LOCAL KNOWLEDGE

There has been a great environmental injustice imposed on [Northway's] tribal land and people. ...the fact is that Northway is a fine example of environmental racism which calls for environmental justice.

- Belinda Thomas, 1995 (46)

### **The Significance of Uncertainty**

The phrase “sound science” is often used to imply that research should provide conclusive proof (278), but science provides evidence for interpretation, not proof. The scientific method was described and evolved in the context of controlled laboratory experimentation, as illustrated by classical physics and chemistry. This approach has allowed the acquisition of basic knowledge while minimizing uncertainty. Scientific theories are never proven, but are rather demonstrated and refined by the acquisition of multiple lines of evidence. Environmental science is necessarily observational and lacks the opportunity for investigators to control all relevant variables (279). While such research is critical to understanding local environments and the planet itself, typical standards of proof are unrealistic because in many cases critical knowledge is lacking and inferences must be made. This is where the precautionary principle comes in: the idea that we can use limited data and inferential knowledge to make wise choices regarding the avoidance of risk, even without a full understanding of the mechanisms of harm (89, 280-283).

In human toxicology experimental control is not possible and observational data are inherently confounded by myriad dynamic and complex factors, so proof is especially elusive (72). US industries easily hide in this refuge of uncertainty, demanding proof before regulation will be tolerated (284-286). The scientific method is even sometimes directly exploited by corporate interests that produce intentionally weak studies to confuse discussion of toxic hazards (287-290). The injustice of the risk assessment approach is that powerful forces are able to subject small communities to far greater health risks than they would take themselves, most often in response to a corporate mandate for profit (289, 291-294).

The conflation of legal systems that insist on certainty beyond the shadow of doubt with science, where the shadow of doubt is never absent, seems central to the problem. The notion that harm should be “proven” rather than avoided is blatantly contrary to the public good, and often perpetuates a dangerous underestimation of credible evidence that harm is in progress. The lack of precaution in regulatory policy has allowed contamination of the biosphere, including human bodies, with highly variable complex mixtures of toxic substances—as Arctic residents are keenly aware (214). Such an uncontrolled global experiment threatens humanity across scales, from alterations in the endocrine signaling and epigenetic programming of tissue in the womb of one woman, to our physical and intellectual fitness as a society. And yet, “harm (295)” is essentially impossible to establish.

Instead of demanding proof in the way of documented details regarding the levels of exposure, mechanisms of action, and abatement with decreased exposure (247), we need approaches that expect the irresolvable uncertainty that is inherent to human and environmental health research (65, 296, 297). A new paradigm that recognizes and anticipates the interaction of multiple factors and the feedbacks between them is needed. Scientific knowledge of the toxicological interconnectedness of families and biomarkers of exposure *prior* to disease needs to be exploited and applied inferentially to protect human physiology and the human genome itself (298). Two especially relevant concepts in complex systems theory are 1) the emerging properties and phenomena that develop from such connectivity cannot be scientifically predicted (which does not mean we should not try), and 2) the critical importance of initial conditions (299).

Responsible policies in complex situations include an adaptive, weight of evidence philosophy of precaution. Likewise, in order to support efforts at elucidating, averting, and mitigating these problems, we need applied research approaches that anticipate complex and uncertain results. While great strides have been made in creating relevant and realistic laboratory models of biological systems, the developing principles of endocrine disruption represent that central problem of complexity: the impossibility of predicting emerging phenomenon.

## **Local Production of Health Knowledge**

### ***Northway's Right to Know***

There are many important reasons for epidemiologists and agencies to shy away from health problems that communities suspect are related to environmental pollution in rural Alaska, such as small population numbers, a lack of documented exposures, and the possibility that initiating such research would frighten people away from eating good foods. Alarm in rural Alaska, however, is long since past and many questions remain. Despite those concerns, and the plethora of evidence this dissertation begins to review, standard dogma assumes that effects from ecological exposure to toxic chemicals are negligible, if they occur at all. For example, only two alternatives are given by epidemiologists in a report from the State of Alaska:

Thousands of studies have examined the potential health effects of PCBs and related compounds. The results of these studies have often been conflicting and difficult to interpret. Overall, we conclude that there is some small, unproven but theoretical risk of subtle health effects related to low-level exposure to PCB-like chemicals. These subtle effects may be impossible to detect with existing scientific and medical technology. Alternatively, there may be no adverse effects resulting from low-level PCB exposures such as those encountered through consumption of subsistence foods or store-bought foods (52).

To the contrary, the Northway Health Study demonstrates that historically contextual research, based on local concerns and observations, *can* detect subtle and complex effects of exposure to contaminants. Communities have a right to the insight that local application of scientific principles can provide, despite the uncertainty (300). Indeed, credible and relevant knowledge applicable to rural Alaska is needed and community based research is a promising approach to a variety of environmental health questions.

### ***Learning from Northway***

Likewise, the academic and civil communities would benefit from locally derived knowledge regarding exposures, trends, and the results of any related health

interventions. Local health knowledge production has the potential to both decrease uncertainty and enhance resilience across population scales. Research approaches in native communities have changed radically in recent decades. Conducting research with communities, is a different process than conducting research on communities (301). Community based research is gaining popularity as researchers recognize the value of local knowledge and earn the trust of local people by performing relevant and useful work. The assertion of government to government relations by Alaska's tribes has also contributed to the normalization of community based projects that include local responsibility and ownership (302).

Because locally credible studies of environmental health require information about local conditions, they are a natural forum for the integration of the sciences with local knowledge. The honest integration of these knowledge systems offers a deeper understanding of health conditions at a local scale, likely with broader implications, as demonstrated by the Northway Health Study. The engagement of local residents is essential for the design of useful health studies in small communities because they know the experience of the community, and also because very high participation rates are needed for patterns to be visible. After decades of distrustful relationships with researchers of many fields (27), particularly toxic waste risk assessment (4), engagement is unlikely without substantial local ownership. When people are respected and credited for the expected production of knowledge, they are more interested in sharing their intellectual property and the potential of the project is much, much greater.

While interest in native knowledge has increased with regard to climate change, little has been done to document or investigate perceptions related to contaminants. Given the complexity of real world situations, an integration of local observations and ideas with environmental chemistry and toxicology is really the only locally credible way to approach small studies of environmental health. All the information for this study came from Northway residents. The author simply organized local knowledge, applied statistical analysis, referred to related literature, and evaluated the various lines of evidence. The study validates concerns expressed by Northway residents and begins to clarify the basis of some vague perceptions, while raising difficult and important questions.

Although most isolated communities with Formerly Used Defense Sites have not documented their local situation with respect to possible historic exposures, local individuals have thoughtful insights and collectively, each community has the historic information needed to “test” their suspicions and provide most-likely answers to lingering questions. This kind of local knowledge production is bound to be more realistic and relevant for any community. These ideas are not new (61, 303), but need application in Alaska’s many Formerly Used Defense Site villages. More broadly, learning from Northway and similar situations, would mean recognizing the delicacy of human biology with respect to the inclusion of contaminants in health research, while improving related public policy toward eliminating endocrine disrupting chemicals from the biosphere.

### **Toward Environmental Justice**

Trends across national and global regions show that minority and low-income communities are exposed to more toxicological hazards, and there is extensive evidence that pollution is one reason these communities tend to suffer greater rates of health problems (55). Exposure to pollution occurs along a complex spectrum, rather than with clear distinction between rich and poor, and all of us, not just “the poor” are at risk (304). However, minority and low-income communities generally face a greater multitude of direct and indirect health hazards.

These issues are recognized by the National Academies Institute of Medicine (IM), which published a unique and important document in 1999: *Toward Environmental Justice: Research, Education, and Health Policy Needs* (305). While State of Alaska agencies make little mention of Environmental Justice in their public outreach (the Department of Transportation seems to be the only state agency with an internet page devoted to the issue (306)) a reinvigoration of the Federal Interagency Working Group on Environmental Justice, created in 1994, seems to be underway (294). The IM recommendations are listed here:

Recommendation 1. A coordinated effort among federal, state, and local public health agencies is needed to improve the collection and coordination of environmental health information and to better link it to specific populations and communities of concern.



Recommendation 2. Public health research related to environmental justice should engender three principles: improve the science base, involve the affected populations, and communicate the findings to all stakeholders

Recommendation 3. The committee recommends that environmental justice in general and specific environmental hazards in particular be the focus of educational efforts to improve the understanding of these issues among community residents and health professionals, including medical, nursing, and public health practitioners. This would include the following:

- ✱ enhancing health professionals' knowledge of environmental health and justice issues,
- ✱ increasing the number of health professionals specializing in environmental and occupational medicine, and
- ✱ improving the awareness and understanding of these issues by the general public.

Recommendation 4. In instances in which the science is incomplete with respect to environmental health and justice issues, the committee urges policymakers to exercise caution on behalf of the affected communities, particularly those that have the least access to medical, political, and economic resources, taking reasonable precautions to safeguard against or minimize adverse health outcomes.

Strong leadership, and political will to confront uncomfortable questions with no easy answers, will be required at all levels of governance to implement these important recommendations in Alaska. The possibilities for research are essentially endless, and Alaska's relative isolation from many sources of contamination offer an important opportunity to learn of and from potentially related phenomena. A few possibilities to begin moving toward Environmental Justice are suggested here:

\* Local disease registries should be established statewide, and Community Health Aids (CHAs) trained to maintain them. Local control of sensitive local knowledge is appropriate, but compatibility is critical for research value. A statewide network of disease registries will be most useful and effective if CHAs help guide the development of protocols and software for community clinics to use.

\* An independent survey of the local wild species that Alaskans eat in terms of nutritional benefits and known and suspected toxicological risks is needed across the state. Some research has begun in coastal communities (306), with little reference to extensive toxicological literature that suggests that regulatory guidelines are inadequate to estimate the complex physiological repercussions of chronic low-dose exposures.

\* Alaska State agencies should work with non-governmental organizations like the Alaska Collaborative on Health and Environment (AKCHE) to disseminate credible and relevant information to communities with interactive multi-media formats that encourage use and discussion across generations and in diverse settings, including the multiple risk factors of metabolic syndrome.

\* Concepts of environmental health should be increased in high school curricula in ways that can be made locally relevant and informative in terms of food safety. Such lessons should also include the hazards of commercially mass-produced foods and promote the localization of food production to whatever extent possible.

## **Conclusion**

Remediation was welcomed in the 1990s, yet contaminants are still an important issue. People of Northway face many repercussions resulting from acculturation and continuing rapid environmental change. In Northway and throughout Alaska, the wage / market economy, land use, and habitat changes are all important factors that continue to pressure rural residents to shift away from wild foods. In many communities, a lingering perception of harm from military waste aggravates feelings of powerlessness and confusion, affecting food choice and many aspects of health. Additional research into various patterns is possible if locally based, but must have more promise of definitive results and benefits to be derived in the way of compensatory response.

Negative changes to Alaska Native health have been linked and attributed to lifestyle changes (307-309). Alcohol, tobacco, processed foods, and decreased physical

activity are all very real contributors to disease in rural Alaska and around the world (310). There is no doubt that wild foods are highly nutritious (87). There is also evidence, however, that contaminants are present in bodily tissue at biologically active levels in Alaska (311, 312) and many other places (244). While risk assessments have been numerous, detailed studies of human contaminant exposure and the possible effects have been rare in Alaska, especially in the interior, where communities are not as prone to exposure to pollution via the global marine food web. Limited documentation makes investigating such risks more difficult, but not impossible.

Realities of exposure to petroleum, persistent organic pollutants, and other contaminants are different from village to village across Alaska, with effects that inevitably vary in severity. The Northway study provides credible evidence that the effects of contaminant exposure are likely to be real, if subtle, and that local knowledge is a promising way to study them. When personal knowledge is systematically collected, memories become data that can be analyzed. While such data cannot be assumed perfect, they are considered to be reliable (127). Cancer is an all too common theme, and not expected to be the most sensitive outcome of biologically active pollution (137). The need for answers in communities is compelling but barriers to data collection are substantial, even for community members. Nonetheless, it is likely that many affected villages could document their collective knowledge and answer at least some of their historic and on-going questions with locally controlled research. This process of evaluating long-held suspicions allowed Northway residents to learn a great deal from the field of environmental toxicology. Given proper support and recognition, such locally produced health knowledge could likewise contribute much insight to the toxicological literature.

Continued systemic neglect of the connections between pollution and health is unacceptable. Legal action, however, is formidable, cost prohibitive, and unlikely to result in satisfactory justice. Despite uncertainty, research focused on answering local questions presents an opportunity for everyone to learn about the health impacts of ecological exposures from local memories. Sharing control over research does not have to mean relinquishing academic standards or the right to disclose findings, but rather commits academic and other researchers to conduct and disclose studies with respect for individual and community concerns, desires, knowledge, and identity.

Among people in Northway, there seems to be an understanding that health is interactive and complex, but less understanding of policies that have left them feeling injured with no recourse. More than anything, Northway residents seem to want to know what the health risks are so they can learn to protect themselves and their children. This desire may capture the essential paradigm shift we need to accommodate the value and limitation of science: a move from risk management, to educated risk avoidance.

## CONCLUSION

Difficult questions of historic environmental exposures can be approached with the recognition that collective local knowledge *is* evidence. Together with remedial documents and toxicological literature, evidence based on memories of undocumented history is a fleeting opportunity to elucidate most-reasonable explanations of related patterns of illness. This project faced substantial epidemiological limitations and harm from military and other federal waste has not been definitively proven. However, even extensive research would not remove all uncertainty, and while each line of evidence has unique limitations, the data based on memories, the remedial documents, and the toxicological literature each corroborates the others. The most important question for people who experienced this unintended and uncontrolled experiment is “What now?” That question was mostly beyond the scope of this project, but a few possibilities are suggested here.

✱ *Thyroid and persistent pesticides/other POPs.* A study of the collective results of newborn and other thyroid function screening data, coupled with levels of persistent organic pollutants in blood and detailed information about the family’s historic fish consumption could help evaluate the current risk of historic exposures.

✱ *Metabolic problems and the Haines Fairbanks Pipeline corridor.* A thorough study of metabolic disorders in Northway would include detailed information about the extent and life-stage timing of pipeline and other resource uses and the relative timing of multiple health problems, as well as personal information such as diet, exercise, habits, central obesity, and biochemical data including triglyceride and lipid profiles. Current blood levels of dioxin and dioxin-like chemicals would also be informative. Because most, but not all, communities of the Upper Tanana used the Haines Fairbanks Pipeline, unique and potentially valuable research opportunities exist—if the people are willing.

✱ *The possibility of neurological effects from lead and other neurotoxics.* It is suggested by the study that children in Northway were and may still be at an elevated risk for related developmental problems, although this was not studied. If toxics contributed to these other problems, neurological effects like attention deficits and

learning disabilities would have been likely because the neurological system is extremely sensitive. Our study identified roadside roots as a pathway for lead, and historic fish and airport muskrat as pathways for persistent organic pollutants. Like lead, POPs are known to interfere with the development of the brain in the womb and throughout youth. Those exposures must have been more significant in years past. A study of problems like learning disabilities and attention deficits, as well as contaminant levels in blood, could be informative in terms of toxicological data, and might document a contribution of harm—although a responsible party would be difficult to identify. Tests for lead are more readily available than tests for persistent organics. Such research would have to be locally controlled and trusted for obvious reasons, and would be very challenging. Again, “proof” would be unlikely, but adding to the weight of evidence could help prompt attention toward mitigating such effects, locally and across the state.

Extensive circumstantial evidence, taken together, builds a strong case for the inferential knowledge developed so far. However, the Northway Health Study (NHS) is clearly riddled with uncertainty and there are any number of possible studies that would further clarify details of the toxic legacy in Northway. However, without more promise of definitive results and compensatory response, Northway residents are unlikely to be interested. Considerable potential exists, however, for the development and implementation of helpful interventions. For example, related ‘Living Well’ development courses could teach such essentials as nutrition and cooking, with an emphasis on thyroid and metabolic health. Four general suggestions will be made in the final report to Northway, with possible resources to help begin their implementation:

- 1) Track the incidence of disease with a registry, be it formal or informal;
- 2) Screen children, youth, and women of child bearing age for blood lead levels, and thyroid and metabolic function;
- 3) Send samples of whitefish and pike from important fisheries to the Alaska Department of Environmental Conservation Fish Monitoring Program for analysis; and
- 4) Localize the food system as much as possible; include gardening as well as cooperative buying power to acquire bulk organic whole foods.

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## **APPENDICES**



## Appendix A: Letter to initial informants

May, 2006

Dear

Thank you for participating in the harvest interviews of the Northway Harvest and Health Project. The information you provided about the wild foods that are important to you allowed us to prioritize the sampling plan, and I learned a lot from spending a little time with each of you. Gerald and I hope that you will continue to participate by looking at the sampling plan and telling us what you think, and/or volunteer to help the student interns collect samples. There are some things I didn't always say that I that I should have

- I am not here to say that you should be worried about contamination, or to say that you shouldn't be. I wonder and I want to work with you to figure it out. I definitely agree that these foods are way, way better for people than the pumped-up, crossbred foods from the store—maybe even if they are a little contaminated, as some of you suggested. There is a legitimate suspicion that some of the waste got into the foods and contributed to cancer around Northway. On the other hand, if they aren't contaminated, these are probably some of the healthiest foods on the planet. We want to test those suspicions and document the evidence, even though we probably will not "prove" anything.
- We do not actually have major funding for this project yet. We have submitted a big proposal to the National Institute of Environmental Health, and we are continuing to apply for funding through private foundations. I have used a fellowship and a couple of small grants to start, and the more progress we show the better the chance of getting a big grant that will actually pay for the analysis of the samples (big time expensive). We will collect samples of a lot of different foods, but we may not get enough funding to analyze them all.
- The point of this study is not to "prove" anything. Scientific studies support or refute ideas, but it is virtually impossible to prove anything in the real and very complicated world. We want to test two main hypotheses: 1) that old waste sites contaminated local water and food webs, and 2) that water and food web contamination contributed to cancer and other health problems around Northway. We will be able to say how much contamination is in foods from a few selected locations, but we will never know how different those levels were 20 years ago. This year we will focus on places people suspect of contamination, even though foods from those places are used less now. Next year we'll take samples from further away to see if there are differences in contamination or nutritional value.
- Instead of trying to prove something, the goal is making real information available to residents of Northway so that they (you!) can make informed decisions. Some foods are better than others, at the store and in the natural environment. We might not be able to figure out exactly why everyone who got cancer got it, and we cannot recreate history, but we can document the benefits and risks of wild harvest as well as the benefits and risks of store bought foods. Knowing which foods are 'clean,' and where the exceptions are, should help promote the healthiest choices.
- The health review portion of the study, where we look at how contaminants have influenced health in Northway, will include how perceptions of contaminants have influenced the decisions people make and the health implications of those decisions—like eating store bought foods.

The next page is a summary of some of the things people told me, including the species people wanted sampled most. Some samples have already been collected, but we won't send them to the lab until we get funding. We want to know if this sampling plan will provide information that will be valuable to you or how it could do better. I appreciate your taking the time to talk with me. I'll be gone until late June, but will be around a lot this summer. It has been a real privilege and pleasure to work in Northway and I am looking forward to getting back.

### Summary of interview data

36 interviews with 44 individuals  
 20 men, 24 women  
 Age range 18 – 86, average age 57 years old  
 81% lifetime in Northway (born and now, may have spent up to 20 years away )  
 All informants lived more than 20 years in Northway (except one 18 year old)  
 68% Upper Tanana Athabaskan  
 18% Upper Tanana Athabaskan and White  
 10% White  
 2% Distant Athabaskan (farther than Tanacross)  
 2% Distant Athabaskan and White

informants	age (yrs)
3	<40
9	40-49
12	50-59
11	60-69
6	70-79
3	>80

Species suggested in order mentioned	Location suggested (suspected sites)
Whitefish	Moose creek
Muskrat	Airstrip lakes
Roots	Airstrip/FAA
Raspberries	Main pipeline corridor
LB Cranberries	Feeder pipes along N rd
Blueberries	Bog around airport lakes
Rabbits	Tacan Road
Pike	Fish Creek
Ducks	
Moose	
Grouse/ptarmigan	
Burbot	
Caribou	
M Candy	Airstrip lakes?
Grayling	Nabesna Slough
Beaver	
Trout	

### Main reasons for changing harvest: some personal, some community

Modern life includes white/ easy/ store/ lazy food, road/ cars, work/ money, access to grocery stores, food stamps/ welfare

Contaminants

Flooding of fish camp

Land less productive

Harvest regulations

Loss of elders/lost knowledge

School

Liquor

### Health concerns thought to be potentially related

Cancer

Thyroid problems

Learning disabilities

Autoimmune diseases

Reproductive problems

Most participants stated that they are concerned that local foods have been contaminated, and that they are concerned because of cancer. Of course, different people have different levels of concern and everybody knows that no one knows exactly what is in the foods. I didn't bring up cancer, or even ask about health, but almost everyone spoke of a connection and several spoke of other conditions they thought might be related. Just more than half of you implied that contaminants influence how much or where you harvest. Almost all informants mentioned at least one place they do not harvest because of contaminants (esp the pipeline corridor), and more suggestions for testing. The most common concerns are listed in the sampling plan above. These foods are still consumed, though less commonly—in part, I am told, because their populations are less abundant (for many reasons that have mostly not been documented). Everyone seems to understand that store bought foods are not as healthy as these foods are, except they worry about contaminants.

Most people seem to think harvest really declined in the 1970s, mostly because of increasing access to and pressure toward wage employment and grocery stores—most folks named at least a few reasons for the decline. The only one that was never named as the main reason was ANCSA's abolition of traditional rights, which was mentioned twice. In the final report, we will address how changes in harvest might have changed exposure to contamination over time. Regardless of actual levels, perceptions of contaminants have contributed to changing harvest patterns, especially among younger harvesters. I thank you again for sharing your intellectual property with me, I have learned a lot.

Anna Godduhn  
 (907) 452-1706

## Appendix B: Partnership Agreement

### Partnership Agreement regarding the Northway Harvest and Health Project (NHHP)

The University of Alaska Fairbanks

The Northway Village Council

January 2006

Whereas rural food security is of importance for the community of Northway Village, Alaska, as well as the University of Alaska and the wider research community; and

Whereas a collaborative evaluation of the benefits and risks of traditional foods in Northway will empower local decision making to improve human health, as well as contribute to academic efforts to understand human health in an ecological and cultural context; and


Whereas contaminants and perception of contaminants each have the potential to cause adverse effects on physiological and cultural health;

The Northway Village Council and the University of Alaska Fairbanks enter into the following partnership agreement to conduct the Northway Harvest and Health Project:

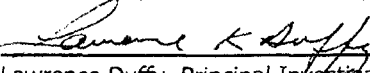
The NHHP will be a systematic measurement of current exposure pathways of environmental contaminants in commonly consumed traditional foods, and an evaluation of how contaminants and perceptions of contaminants have influenced health and food security in Northway Village. As part of such an evaluation, selected nutritional values of traditional foods will be documented. Rather than conduct a typical risk assessment, the study will investigate local concerns to test longstanding hypotheses in a manner that is locally and scientifically credible.

The exposure pathways assessment will be a relatively straightforward attempt to answer the general questions: "What is in the foods?" and "Which foods are safe and which foods are not?" Other research questions will include the extent to which traditional foods have been avoided because of perceptions of contaminants, and whether instances of avoidance have been protective or detrimental for health. For such a study to be realistic, interpretations will necessarily acknowledge and account for multiple factors that influence food systems that are not directly related to contaminants—such as climate and land use changes, regulatory regimes, store bought foods and alcohol, and Alaska's economy.

The study will be collaboratively designed, implemented, interpreted, and reported. The Northway Village Council and the University of Alaska Fairbanks hereby commit to meaningful collaboration throughout the processes of research. Members of the Northway Village Council will have an integrated role throughout the study, helping to: make decisions in study design, arrange interviews and sample collection, interpret qualitative community based data, contribute to and/or review written reports, and communicate findings to the community. Responsibility for the protection of original data will belong with the University of Alaska Fairbanks, where it will be held indefinitely and made accessible to interested parties and for follow-up research. The University shall retain rights to publish findings based on these data. Progress reports and other documents of the study will be public information, while access to confidential information is and will be restricted to the research team. Copies of all reports, and data as requested, will be held by the Northway Village Council.



Gerald Albert, President, Northway Village Council



Lawrence Duffy, Principal Investigator, Northway Harvest and Health Project



Steve Jones, Chancellor, University of Alaska Fairbanks

**Appendix C: Survey Instruments**

These survey instruments have been reformatted to fit these pages.

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C-2 Household Questionnaire .....129

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C-4 Historic Household Interview .....132

## Appendix C-1: Initial Interview

name \_\_\_\_\_

date \_\_\_\_\_

***Thank you for talking with us about harvest and contamination. Do you have any questions?***

***Please feel free to say so if the questions don't make sense or if you would like to take a break. You can say you don't want to answer any question we ask and you can stop at any time if you don't want to answer any more questions. You are welcome to ask your own questions at any time.***

Have you lived in Northway your whole life? \_\_\_\_\_ (if no, how long?) \_\_\_\_\_

Did your parents live here? \_\_\_\_\_

How old are you? \_\_\_\_\_

How often do you travel outside the village? \_\_\_\_\_

Do you remember where you used to go for hunting and fishing when you were a kid? (Show on map if possible; what species, what season)

Do you still harvest around there? \_\_\_\_\_

*if no* Why did you stop?

When was that?

*if b/c of contaminants:* What made you think there might be a danger? (physical evidence (smell, etc) of waste? something about the animals/plants that live there or go there? (number in population, any physical anomalies/new qualities, # young, odd behavior, etc...))

Does anyone harvest there anymore? \_\_\_\_\_

Where do you go to harvest those animals/plants now (show on map if possible)?

On a scale of one to ten, if one is none and ten is all, how much of the food that people in Northway eat comes from the land and rivers?

How has that changed through time? (steady decline, or up and down – depending... on what?)

*If < 65:* Do you remember what your parents and grandparents said about how life changed when the Army came to build the airport and the road?

*If > 65:* How did life change when the Army came to build the airport and the road?

Are there any places where you don't harvest because you are nervous about contaminants? (where?)

Do you remember what things you saw or heard that made you concerned about contamination? (when?)

Do other people in Northway worry much about contamination? \_\_\_\_\_

*if yes:* When did they start?

What questions do you have about the foods around Northway? What foods would you like to see tested?

## Appendix C-2: Household Questionnaire

### Northway Household/Family Health Questionnaire

*a community based approach to environmental health research*

**This questionnaire should be filled out by a head of the household (either one, if there are two). You can call anyone on the Health Study Team if you have questions.**

**Please answer all the questions as completely as possible.**

**Use additional paper if necessary.**

#### Household Characteristics

##### 1. How many people live in your household now?

(please include and circle yourself)

		male	female
children	under 5	_____	_____
children	5 to 9	_____	_____
youth	10 to 15	_____	_____
youth	16 to 20	_____	_____
young adults	21 to 40	_____	_____
older adults	41 to 60	_____	_____
elders	over 60	_____	_____

##### 2. Where is your home located now?

\_\_\_\_\_ In the village  
 \_\_\_\_\_ Along Northway Road  
 \_\_\_\_\_ Northway Junction (within 1 mile)  
 \_\_\_\_\_ Along the Highway

##### 3. Where did the heads of the household grow up?

(please write what years)

woman	man	
_____	_____	In the village
_____	_____	Along N. Road
_____	_____	Junction (w/in one mile)
_____	_____	Along the Highway
_____	_____	Somewhere else

##### 4. Where else have the heads of household lived? (please write what years)

woman	man	
_____	_____	In the village
_____	_____	Along N. Road
_____	_____	Junction (~one mile)
_____	_____	Along the Highway
_____	_____	Somewhere else

**5. This question is partly about times when your current household probably did not exist, but please try to answer it completely. Use the household you were living in at the time – probably your parents'. Also use your parents' if you were not born yet.**

In each decade	List water sources			Rank meats eaten most (put letters in order of most-eaten)		
	woman	man		woman	man	
1950s			river, lakes, or ponds (name)			beef (b)
1960s			moose creek			caribou (c)
1970s			old washeteria			chicken (ck)
1980s			household well			moose (m)
1990s			pump & haul			muskrat (mr)
2000s			corporation well			pork (p)
			FAA			rabbit (r)
			bottled water			salmon (s)
						whitefish (w)
						wild chickn(wc)

##### 6. How many children have the woman and man heads of household raised over their lives?

	boys	girls		boys	girls
woman	her own	_____	man	his own	_____
	adopted	_____		adopted	_____
	total	_____		total	_____

**7. Does your family eat a lot of roots? How has that changed over time? (please estimate # times per week, month, or year)**

### Household Health

*Please include everyone living in your home now, regardless of blood relations. Also include all the kids your current household has raised who do NOT live in another household in Northway.*

**7. If anyone in your home is on medication please state gender, age, condition being treated, and date of diagnosis:**

**8. Please briefly describe any reproductive problems, including but not limited to difficulty getting pregnant, miscarriages, and premature or low-weight births (date, condition of baby and mother, and outcome):**

**9. Please list any deaths (gender, age, year, and cause; historical deaths will be documented later, so please include only deaths that have occurred from *within your current household*.):**

*For these three questions, please give gender, age at diagnosis, diagnosis, year of diagnosis, treatment-if any, and current status.*

**10. Does anyone in your household have thyroid problems?**

**11. Has anyone in your household been diagnosed with diabetes or pre-diabetes?**

**12. Has anyone in your household been diagnosed with cancer?** Historical cancers will be documented later, so please include only cancers that have occurred *within your current household*.):

**13. What are your other health concerns?**

**14. Do the heads of household smoke?**  
quit

**if yes or**

**woman** regularly \_\_\_ sometimes \_\_\_ rarely \_\_\_ no \_\_\_ yrs of smoking \_\_\_ when quit \_\_\_  
**man** regularly \_\_\_ sometimes \_\_\_ rarely \_\_\_ no \_\_\_ yrs of smoking \_\_\_ when quit \_\_\_

**15. Does anyone smoke inside the house now?** regularly \_\_\_ sometimes \_\_\_ rarely \_\_\_ no \_\_\_

If not, did they ever?

yes \_\_\_ no \_\_\_

If yes, they used to, give approximate year smoking inside stopped \_\_\_\_\_

Household Code \_\_\_\_\_



## Appendix C-2: Follow-up Phone Call

**Hi, I hope it isn't too much to ask, but I have some follow-up questions about the questionnaire you sent in. Can we set up a time to talk for a few minutes (or do you have some time now)?**

**The old time food and water sources are really important information but it wasn't really clear how your food has changed over time...**

For each decade	List water sources			Rank meats eaten most (put letters in order of most-eaten)		
	woman	man		woman	man	
1950s			surface water			beef (b)
1960s			moose creek (MC)			caribou (c)
			old washeteria (OW)			chicken (ck)
1970s			household well (HW)			moose (m)
1980s			washeteria/truck (TRK)			muskrat (mr)
			corporation well (CW)			pork (p)
1990s			FAA			rabbit (r)
			bottled water (BTL)			salmon (s)
2000s						whitefish (w)
						wild chicken (wc)
						other (name)

**Okay, just a few more questions for your...**

**Did your family pick raspberries from the pipeline along the highway?**

(please estimate # times per week, month, or year. Also, when was that and when quit?)

a lot = every day when the picking was good

sometimes = once or twice a year

rarely = once every couple of years

**Do you know a lot about a household that no longer exists that you would be willing to fill out a questionnaire about?**

others notes:

household code\_\_\_\_\_

## Appendix C-3: Historic Household Interview

### LONG-AGO Household Health Interview

Thank you for participating in the Northway Health Study. Please think carefully about the way things were, and answer the questions as completely as possible. This will take about a half hour. Please let me know if you want to take a break or need to do something else. I can always come back another day.

#### 1. Where was the home located?

- ☐ In the village  
☐ Along Northway Road  
☐ Northway Junction (within 1 mile)  
☐ Along the Highway  
☐ Off Northway Road (Charlieskin, Moose Creek Village, Ten Mile, other \_\_\_\_\_)

#### 2. Approximately what years did the household exist?

#### 3. Where did heads of household grow up?

woman                  man

- \_\_\_\_\_ In the village  
 \_\_\_\_\_ Along N. Road  
 \_\_\_\_\_ Junction (~one mile)  
 \_\_\_\_\_ Along the Highway  
 \_\_\_\_\_ Off N'way Road \_\_\_\_\_  
 \_\_\_\_\_ Somewhere else

#### 4. Where else did the heads of household live?

woman                  man

- \_\_\_\_\_ In the village  
 \_\_\_\_\_ Along N. Road  
 \_\_\_\_\_ Junction (w/in one mile)  
 \_\_\_\_\_ Along the Highway  
 \_\_\_\_\_ Off N'way Road \_\_\_\_\_  
 \_\_\_\_\_ Somewhere else

#### 5. For the family (or heads of household before the household was formed) during each time period...

5.1	list water sources			5.2	rank meats eaten most (put letters in order of most-eaten)		
	woman	man			woman	man	
40s-60s			river, lakes, or ponds (surf)	40s - 60s			beef (b)
			moose creek (MC)				caribou (c)
			old washeteria (OW)				chicken (ck)
70s & 80s			household well (HW)	70s & 80s			moose (m)
			washeteria (W)				muskrat (mr)
			corporation well (CW)				pork (p)
90s & 00s			FAA	90s & 00s			rabbit (r)
			bottled water (B)				salmon (s)
							whitefish (w)
							wild chkn(wc)
							other

a lot = 4+ times per year  
 sometimes = 1-3 times a year  
 rarely = once every couple of years

#### 6. Did the family...

6.1	get raspberries or mushrooms from the highway pipeline?				6.2	get roots from along roadsides? from around the airstrip?			
	a lot	some	rarely	never		a lot	sometimes	rarely	never
40s-60s					40s-60s				
70s - 80s					70s-80s				
90s-00s					90s-00s				

If yes, approximately how many years? \_\_\_\_\_

**7. How many children did the woman and man heads of household have over their lives?**

		boys	girls			boys	girls
<b>woman</b>	her own	_____	_____	<b>man</b>	his own	_____	_____
	adopted	_____	_____		adopted	_____	_____
	total	_____	_____		total	_____	_____

**8. Okay we are getting there, but this question is probably the hardest. I will ask for information about each person in the home, such as their gender and their health conditions. We would like as much detail as possible about any serious health problems then and now. We also want to know about good health. Please include everyone who lived in the household, regardless of blood relations.**

*For each person: Did s/he have thyroid problems, diabetes or pre-diabetes, reproductive problems, or cancer (what type?). (reproductive problems (such as difficulty getting pregnant, miscarriages, premature or low-weight births (less than 7 pounds))*

gender	year of birth	condition(s) young	condition(s) now	Now in Northway?	year and cause of death, if

**9. Did the heads of household smoke?**

**if yes or quit**

**woman** regularly \_\_\_ sometimes \_\_\_ rarely \_\_\_ no \_\_\_ yrs of smoking \_\_\_ when quit \_\_\_  
**man** regularly \_\_\_ sometimes \_\_\_ rarely \_\_\_ no \_\_\_ yrs of smoking \_\_\_ when quit \_\_\_

**10. Did anyone who lived there smoke inside the house?**

regularly \_\_\_ sometimes \_\_\_ rarely \_\_\_ no \_\_\_

**11. How many people who lived there smoked in the house? \_\_\_\_\_**

**12. Do you have any other thoughts or observations about the family?**

Head(s) of Household Name \_\_\_\_\_

Household Code \_\_\_\_\_

**Appendix D: institutional Review Board Approvals**

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D-2: Approval for the Northway Wild Food and Health Project (09-06) ..... 136

**Appendix D-1: Approval for the Northway Harvest Exposure Project (05-31)**

University of Alaska Fairbanks

***INSTITUTIONAL REVIEW BOARD***

Teresa Lyons, Research Committee Coordinator  
 Office of Research Integrity  
 Vice Provost Suite  
 212 West Ridge Research Building  
 P.O. Box 75720  
 (907) 474-7800  
 Fairbanks, AK 99775-7270  
 email: [fvirb@uaf.edu](mailto:fvirb@uaf.edu)

May 6, 2005

Subject: IRB review of Human Subjects Application form IRB # 05-31

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Dear Dr. Duffy,

Members of the University of Alaska Fairbanks Institutional Review Board (IRB) have reviewed the following Human Subjects Application. This protocol will be approved via an expedited review process in accordance with CFR Title 45 §46.101 Category 7: Research on group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

IRB Protocol Number:	05-31
Investigator/Instructor:	Lawrence Duffy, Ph.D.
Title of Project/Course:	<i>The Northway Harvest Exposure Project: A community based approach to contaminant research</i>
Date Received:	April 15, 2005
Date Approved:	May 4, 2005
Annual Continuing Review Report:	April 1 beginning April 1, 2006

Procedural changes or amendments must be reported to the IRB, and no changes may be implemented without prior IRB approval. Congratulations and good luck with this very interesting project.

Teresa Lyons  
 Research Committee Coordinator

## Appendix D-2: Approval for the Northway Wild Food and Health Project (09-06)



### Institutional Review Board

March 4, 2009

To: Larry Duffy, PhD  
Principal Investigator

From: Bridget Stockdale, Research Integrity Administrator  
Office of Research Integrity

Re: IRB Protocol Application

Thank you for submitting the IRB protocol application identified below. This protocol was determined to qualify for expedited review under federal regulations 45 CFR 46.110(F)(7). Therefore the review of your protocol application was done by representative members of the IRB. On behalf of the IRB, I am pleased to inform you that your protocol has been approved.

Protocol #: 09-06

Title: *Northway Wild Food and Health Project (NWFHP)*

Level: Expedited

Received: February 11, 2009 (original)  
February 27, 2009 (final revisions)

Approved: March 4, 2009

Approval expires: March 4, 2010

Renewal: Continuing Review must be completed  
**Note:** We recommend you submit all continuing review documents approximately one month prior to the due date to prevent delays in your research.

*Any modification or change to this protocol must be approved by the IRB prior to implementation. Modification Request Forms are available on the IRB website (<http://www.uaf.edu/irb/forms/mrf.pdf>).*



